Howard - 137

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ATTACK VS SCAN: A COMPARISON OF ENDGAME
AIRCRAFT SURVIVABILITY COMPUTER PROGRAMS

by

James Earl Parr

December 1980

Thesis Advisor: R. E. Ball

Approved for public release; distribution unlimited

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)

ATTACK VS SCAN: A COMPARISON OF ENDGAME AIRCRAFT SURVIVABILITY COMPUTER PROGRAMS

5. TYPE OF REPORT & PERIOD COVERED

Master's Thesis; December 1980

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

James Earl Parr

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

Naval Postgraduate School
Monterey, California 93940

12. REPORT DATE

December 1980

13. NUMBER OF PAGES

120

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aircraft survivability, Aircraft survivability assessment, Endgame computer simulation, Damage mechanism effectiveness

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study compares two computer programs, ATTACK and SCAN, with respect to the utility and validity of each program. The comparison is made from two points of view; a model developer and a consumer.

The utility considers six subject areas; (1) documentation, (2) geometric modeling, (3) P_K/Vulnerable Area Modeling,

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(4) Missile, Warhead and Fuze Modeling, (5) Scenario Simulation and (6) Program Output. SCAN was determined to be superior in every area except for the missile, warhead and fuze modeling area.

For the validity evaluation, equivalent models were developed for a show box target and a simple warhead for both programs. A separate plot technique was used to verify the program results. For the sample models used in the comparison, the results agreed qualitatively with those from the plot technique.

(4) Missile, Warhead and Fuze Modeling, (5) Scenario Simulation and (6) Program Output. SCAN was determined to be superior in every area except for the missile, warhead and fuze modeling area.

For the validity evaluation, equivalent models were developed for a ship box target and a simple warhead for each program. A separate plot technique was used to verify the program results. For the sample models used in the comparison, the results agreed qualitatively with those from the plot technique.

ATTACK vs SCAN: A Comparison of Endgame Aircraft Survivability Computer Programs

by

James Earl Parr
Lieutenant, United States Navy
B.S. University of Utah, 1975

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL
December 1980

ABSTRACT

This study compares two computer programs, ATTACK and SCAN, with respect to the utility and validity of each program. The comparison is made from two points of view; a model developer and a consumer.

The utility considers six subject areas; (1) documentation, (2) geometric modeling, (3) P_K/Vulnerable Area Modeling, (4) Missile, Warhead and Fuze Modeling, (5) Scenario Simulation and (6) Program Output. SCAN was determined to be superior in every area except for the missile, warhead and fuze modeling area.

For the validity evaluation, equivalent models were developed for a shoe box target and a simple warhead for both programs. A separate manual plot technique was used to verify the program results. For the sample models used in the comparison, the results agreed qualitatively with those from the plot technique.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

ACKNOWLEDGEMENTS

Gratitude is extended to the following people for their assistance and/or support during the preparation of this study:

Professor Robert E. Ball, Naval Postgraduate School
Monterey, California

Bruce Nofrey, Pacific Missile Test Center,
Point Mugu, California

Ken Grant, Naval Weapons Center, China Lake, California

Ron Bates, Aeronautical Systems Division, Wright
Patterson Air Force Base

LT Peter W. Taylor, United States Navy

LT Kenneth D. Via, United States Navy

and special thanks to my wife, Constance C. Parr.

I. INTRODUCTION

A survivability assessment of an air target versus a surface to air missile (SAM) includes studies of the missile fly-out and the Endgame. The portion of the missile flight path from the launch phase to the Endgame or terminal phase is the missile fly-out. Two computer programs used to simulate the missile fly-out, MICE-II and TAC ZINGER, are currently being evaluated at the Naval Postgraduate School (NPS). The Endgame includes the missile fuzing sequence for target detection, and the subsequent warhead detonation and evaluates the effectiveness of the damage mechanisms associated with the warhead on a target under specified encounter conditions.

This study compares two computer programs which are currently used to assess the survival capabilities of an aircraft during the Endgame. Both programs can be utilized to determine the effectiveness of a particular fragmentation warhead against a specific target. The programs under consideration are SCAN and ATTACK. SCAN is a digital computer program developed by the Pacific Missile Test Center. Documentation for this program was completed 30 June 1976. ATTACK is the current version of the AIR-TO-AIR TERMINAL SIMULATION (NWC TN4565-1-70) which is a Naval Weapons Center, China Lake revision of methodology

developed at the Pacific Missile Test Center Point Mugu. The ATTACK documentation was published in June 1974.

It should be noted that each of these programs are in use at several facilities throughout the country. Each facility may have slightly modified the programs so that there are many different versions in existence. This study was conducted on the programs as they existed at the Naval Postgraduate School (NPS) during the period from August to December 1980. The installation of SCAN on the NPS IBM 360/67 computer system was completed with little difficulty and required only minor modifications to the program. The ATTACK installation was accomplished with somewhat greater difficulty. The philosophy behind the modifications at NPS and the modifications themselves will be discussed in greater detail in Chapters III and IV.

The scope of the comparison has been divided into two major categories. First, the utility of the two programs, and secondly, the relative validity of each. An attempt has been made to treat these two areas independently.

The utility study is subdivided into six subjects, viewed primarily from two aspects. One aspect is that of the model developer, the other that of a consumer. The model developer is the individual, or group, tasked with the responsibility of preparing the input data such that the resultant computer model will describe the aircraft, missile, warhead, etc. to the degree of accuracy required for a specific application. The consumer is that

individual, or group, who will use the output of the programs. The consumer will also utilize the "canned" models developed by a model developer for various scenarios. For example, he may run one target against several different warheads and compare the results, or vice versa. He also might make slight changes to an existing model and observe the results.

The six subjects to be considered are (1) documentation, chiefly User Manuals, (2) geometric modeling, (3) P_K/ vulnerable area modeling, (4) missile, warhead and fuze modeling, (5) scenario simulation and (6) output. The relative merit of each program will be determined for each subject area and point of view as applicable.

The validity study was accomplished by designing a simple "shoe box" target and simple warhead. The goal was to input common target, missile and warhead models into both programs; place the missile and warhead in identical locations and orientations with respect to the target; detonate the warhead and observe the results. Every effort was made to make the SCAN and ATTACK models as similar as possible. In order to achieve this similarity, many simplifications were required in the model design. Because of these simplifications much of the capability of each of the programs was not utilized. Another reason for selecting a very simple model and scenario was the need to make a judgement on the validity of the outputs.

With a simple system it is possible to sketch the encounter geometry and predict which components will incur damage. The models will be described in detail in Chapter IV, along with a more lengthy discussion on what simplifications were made and why they were necessary.

The intent of this study is to provide guidance to be used by either a model developer or consumer in selecting which program might be more appropriate for a particular application and to establish a level of confidence in one program versus the other.

With a single system it is possible to assess the secondary geometry and predict which components will incur damage. The models will be described in detail in Chapter IV, along with a more in-depth discussion on what simplifications were made and why they were necessary.

The intent of this study is to provide guidance to be used by either a model developer or consumer in selecting which program might be more appropriate for a particular application and to establish a level of confidence in one program versus the other.

II. PHILOSOPHY/METHODOLOGY

A. GENERAL

Prior to a detailed comparison of SCAN and ATTACK it seems appropriate to first briefly summarize the philosophy and the methodology behind each program. This will provide an insight into some of the differences in the programs which will be described later. The intent here is to present, in capsule form, the nature of each program. No attempt will be made in this chapter to evaluate the relative merit of any aspect.

B. ATTACK

The ATTACK program is a Naval Weapons Center, China Lake, revision of a methodology developed at Naval Missile Center, Point Mugu. The objective of ATTACK, as stated in it's User Manual, "is to predict the ability of a missile to detect and destroy an airborne target." To this end, the program provides a Probability of Kill (P_K) assessment for (1) direct hits, (2) blast, (3) multiple fragment (structural), and (4) single fragment (component) damage mechanisms.

The ATTACK program utilizes a traditional approach based on the establishment of a vulnerable area table for

the target. The vulnerable area table is only used with the single fragment (component) model. The table is composed of vulnerable area data for each component in the model as a function of encounter geometry aspect angle, warhead fragment weight and fragment impact velocity.

This program requires four target geometrical representations, one representation for each of the possible damage mechanisms. A fifth representation is needed for the fuzing portion of the program and depends on the type of fuze selected.

The program is intended to provide results for the following purposes:

(1) Weapon system evaluation

(2) Warhead design

(3) Fuze optimization

(4) Aircraft survivability studies

(5) Trade off studies

The methodology for damage assessment is composed of the following classes:

(1) Structural

(a) direct hit model

(b) blast model

(c) multiple fragment model

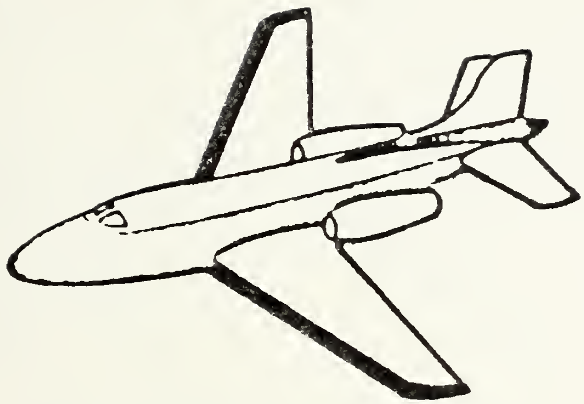
(2) Component

(a) single fragment model

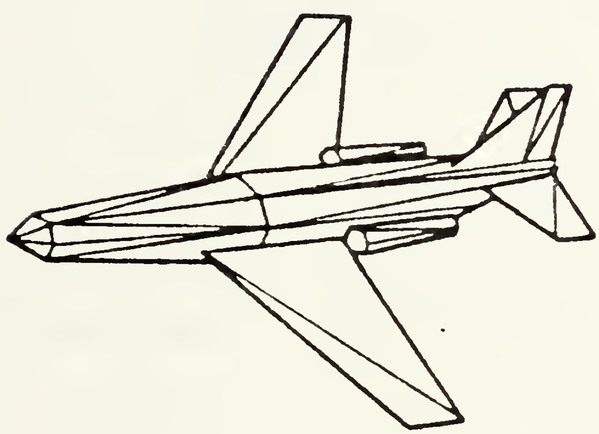
The direct hit model consists of a target representation consisting of triangular plates (see Figure 2-1), and a missile which is represented by a collection of points (see Figure 2-2).

The missile trajectory is determined from a user specified encounter geometry. The program determines if one or more of the missile points will intersect the target and the time of first intersection, or contact, between missile and target. If the first contact occurs before proximity fuzing a direct hit kill is scored and other damage mechanisms are not investigated. If proximity fuzing occurs first, a preempted direct hit is recorded and reported in the output and the other damage mechanisms are examined.

The blast model is composed of a group of cylinders and hemispheric caps surrounding the target body and its extremities (see Figure 2-3). The radius assigned to each of these blast cylinders is a function of both the strength of that particular structure and the amount of explosive charge in the warhead. The radii, which must be determined in a separate analysis, are scaled to a specific encounter altitude. If the warhead detonates within the volume of one of these cylinders, a blast kill occurs and no other



ACTUAL ATTACK



DIRECT HIT MODEL

Figure 2-1 ATTACK Direct Hit Model [1]

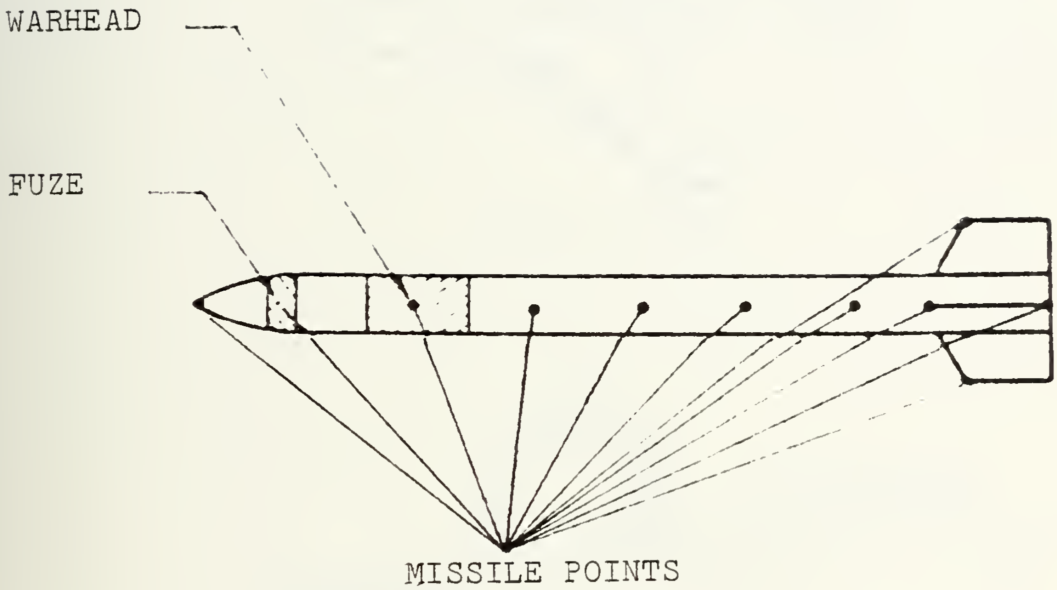
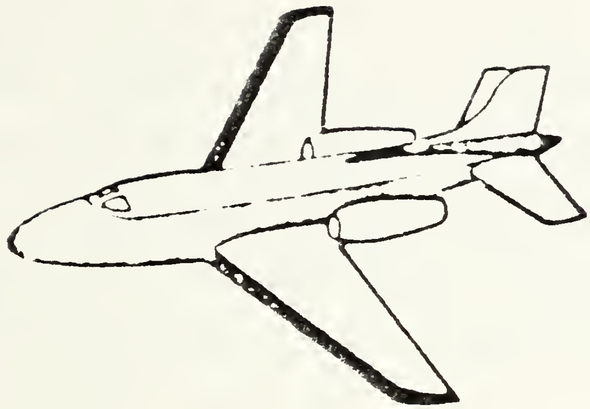
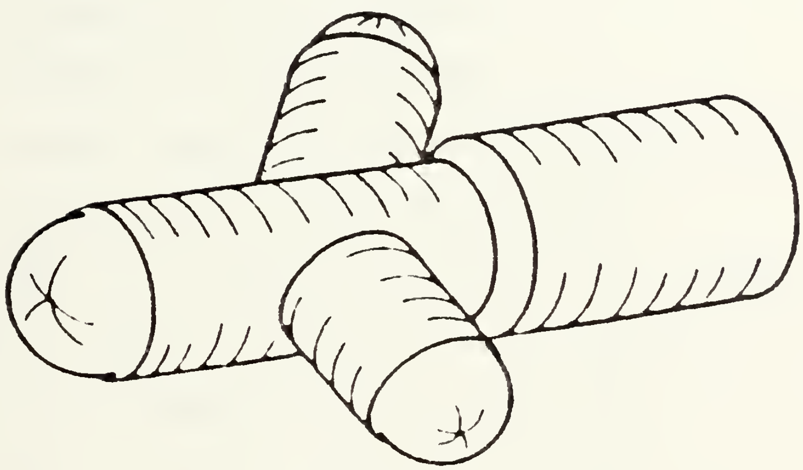


Figure 2-2 ATTACK Missile Geometry [1]



ACTUAL TARGET



BLAST MODEL

Figure 2-3 ATTACK Blast Model [1]

damage mechanisms are considered. If warhead detonation occurs outside the volume defined by the blast cylinders no target damage is attributed to the blast.

The multiple fragment model for structural damage uses a segmented cylindrical target representation as shown in Figure 2-4. The program advances the centroid of the cylinder segment by the target velocity vector from the time of warhead detonation. The fragment dynamics are computed as a function of:

(1) fragment mass

(2) fragment shape

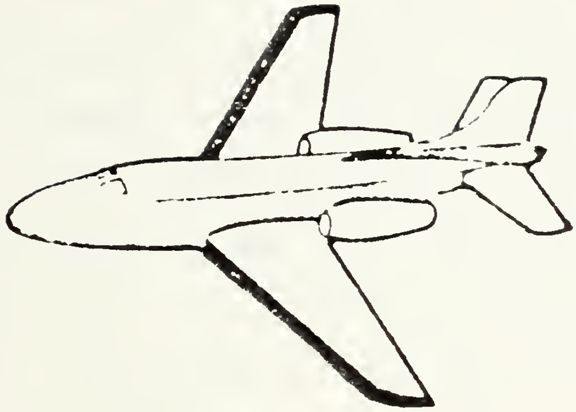
(3) fragment initial velocity

(4) fragment drag coefficient

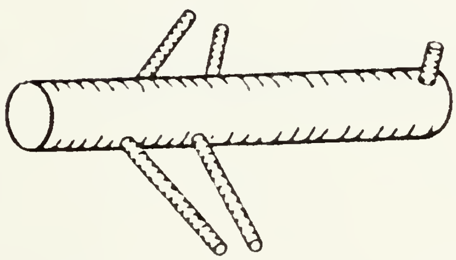
(5) target range and aspect from warhead at detonation

(6) fragment and target flight paths

The number of fragments and associated energies which strike each cylindrical segment is determined by the location of the segment within one or more of the warhead dynamic polar and radial zones. The energy density is calculated and compared with a critical amount of energy specified for that segment. If the calculated value exceeds the specified energy density, a structural kill is assumed.



ACTUAL TARGET



MULTIPLE FRAGMENT MODEL

Figure 2-4 ATTACK Multiple Fragment (Structural) Model [1]

The single fragment or component kill model consists of individual components, represented by spheres (or points), located at appropriate positions around the target coordinate system origin as shown in Figure 2-5. The computational process for P_K pursued in this model is similar to that in the multiple fragment case. The component (sphere) centroid location and radius are used to determine the fractional area (FRACT) of the component within a given polar and radial zone. The ATTACK model considers the fragments to exit the warhead in definable polar and radial zones. Each zone may contain one or more fragment classes (up to seven) with an average fragment weight and average fragment initial velocity for each class.

$$\text{FRACT} = \frac{\text{Portion of the component covered by the fragment spray band } (A_t)}{\text{Component presented area } (A_p)}$$

The distance (DIST) of the component centroid from the warhead origin at detonation is used to compute the exact fragment impact velocity and the striking azimuth and elevation angles for a specific fragment weight class. These parameters are used in conjunction with the vulnerable area tables to compute the appropriate component vulnerable area (A_V). A fragment beam area (FA) within the polar and radial zone boundaries is computed at the distance, DIST. The number of fragments (Q) for each weight class and for each polar/radial zone combination is an input parameter.

AIRCRAFT COMPONENTS (IDEALIZED AS SPHERES)

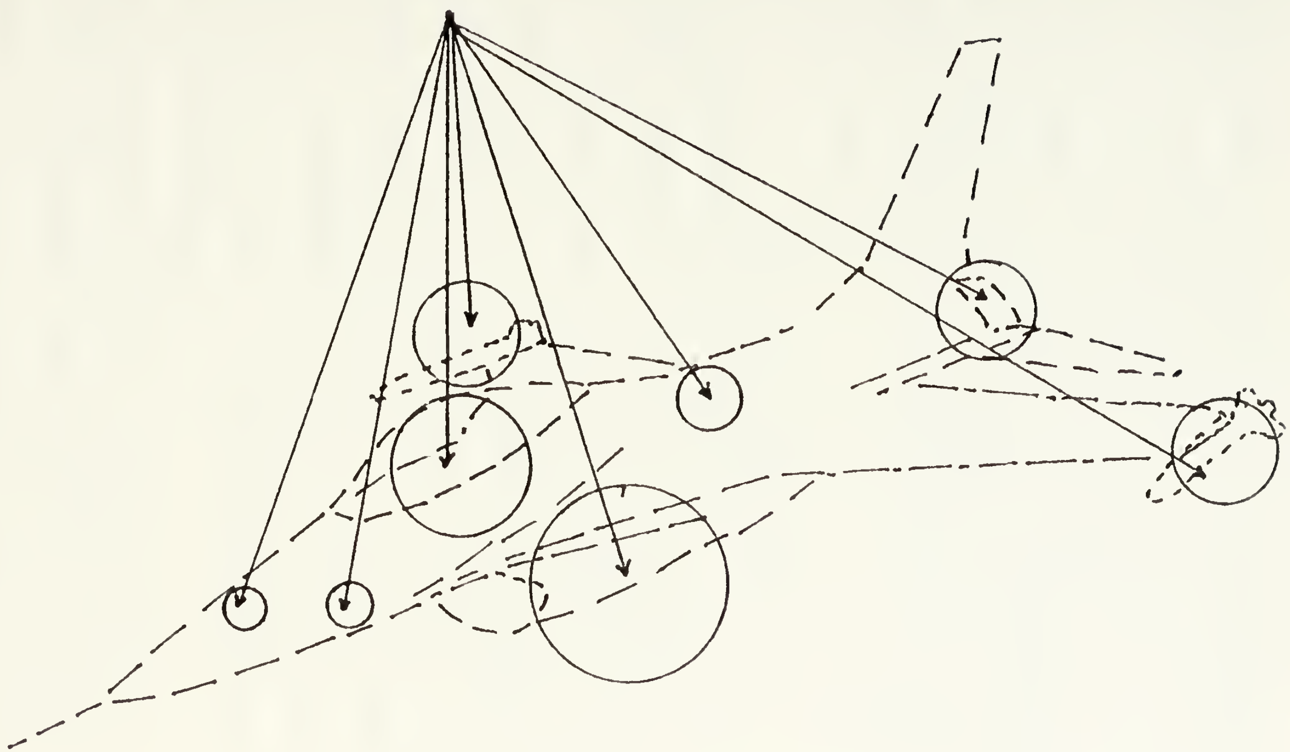


Figure 2-5 Example of ATTACK Single Fragment (Component) Model

Therefore, the fragment spray density, RHO is given by:

$$RHO = \frac{Q}{FA}$$

The expected number of lethal hits (E) for the specified weight class is calculated from:

$$E = RHO * A_V * FRACT$$

The expected number of lethal hits is accumulated for each polar zone, radial zone and fragment weight class and the component probability of Kill (P_K) is computed by the following equation:

$$P_K = 1.0 - EXP\ (-E)$$

(This is an approximate P_K equation)

The Endgame geometry as shown in Figure 2-6 is specified by the user. The missile may be oriented with respect to either the target or to a relative velocity vector. The user may either specify missile miss distance or require the program to generate one randomly from a Gaussian distribution. A standard deviation can be provided by the user for the miss distance. Multiple trajectories may be simulated for each scenario.

For the warhead detonation, the user has the option to choose from ten different fuze logics (an eleventh option has been added to the NPS version and will be discussed in Chapter III). The possibilities include various

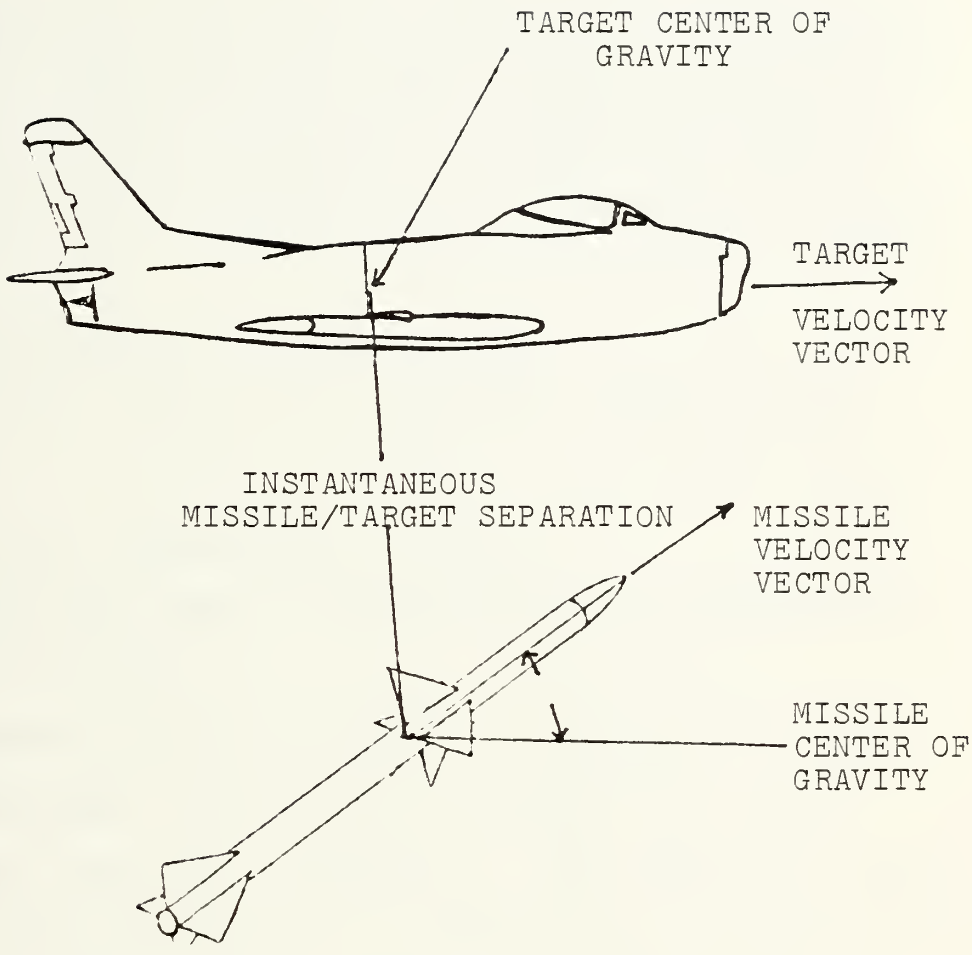


Figure 2-6 Example of Endgame Geometry

types of semi-active doppler fuzes, fixed angle active fuzes, double fixed angle active fuzes and IR fuzes.

C. SCAN

The objective of SCAN, in the words of it's User Manual, is "to predict the probability that an aircraft will survive an attack by a missile armed with a fragmentation warhead." P_K is computed for (1) direct hit, (2) blast and (3) fragment damage.

SCAN can be used to provide data for:

(1) aircraft design from conceptual design to final production

(2) aircraft survivability studies

(3) supporting data for implementation of a particular survivability feature.

The foundation of this program is a complex geometric model of the target. The model is composed of a series of components, where each component is represented by either a box or a quadric surface with bounding planes (e.g. cylinders, cones, etc.). A sample model is shown in Figure 2-7.

Each component is also assigned a P_K value based on one of three types of vulnerability. The three types are:

(1) single fragment vulnerable

(2) energy density vulnerable

(3) area removal vulnerable

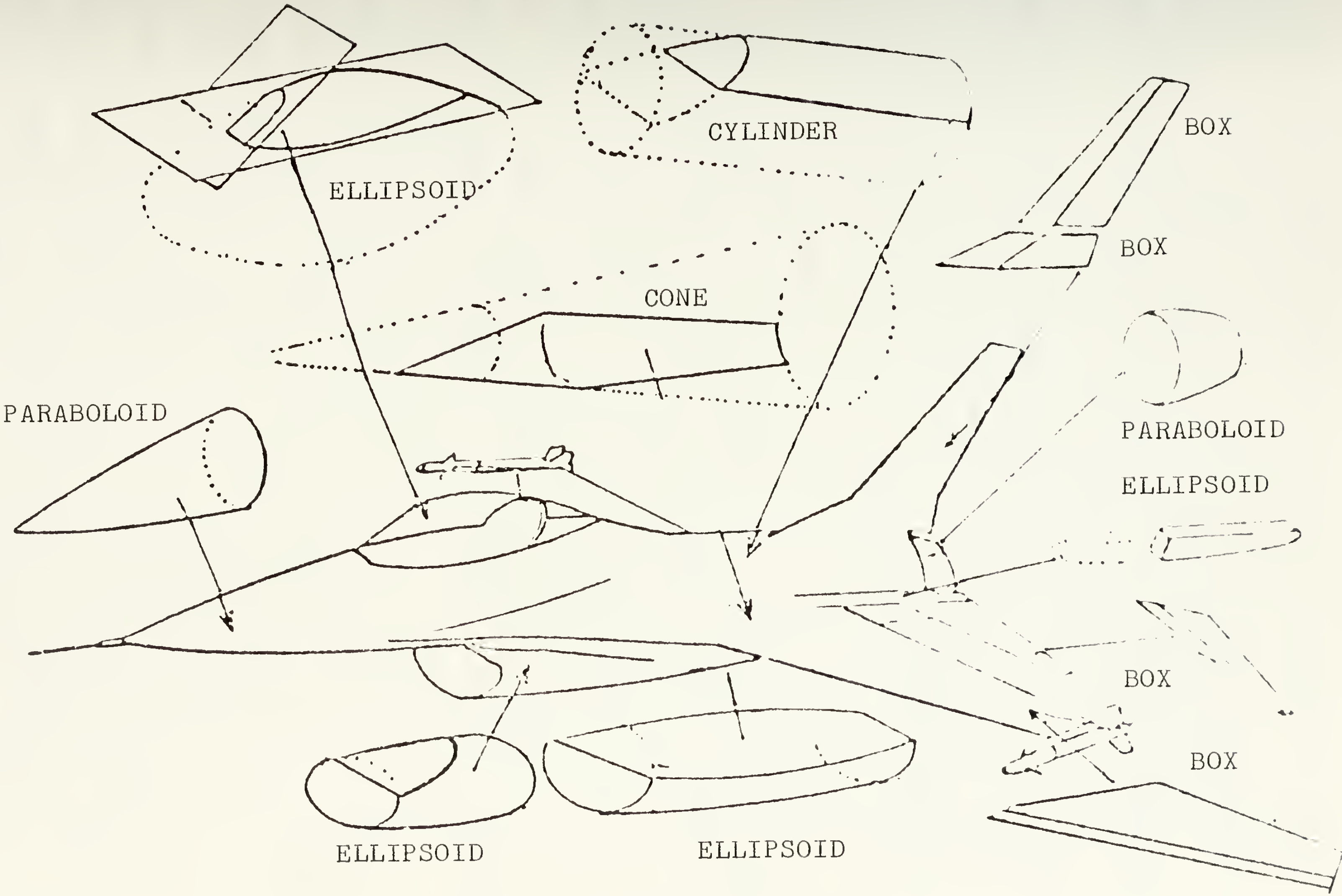


Figure 2-7 Geometric Representation of the Exterior of the F-16 Aircraft [2]

The first type is the probability of component kill given a hit ($P_{K/H}$). This can be expressed as a constant term plus a linear function of fragment mass and of impact velocity and is computed by the following equation:

$$P_{K/H} = PK\ (1) + PK\ (2) * M + PK\ (3) * V$$

where PK (1) is a constant term

PK (2) is the coefficient of the Mass term

PK (3) is the coefficient of the Velocity term

M is the fragment mass (grains)

V is the fragment velocity (ft/sec)

The second type of vulnerability is expressed in terms of a minimum area exposed to a threshold energy density level and as a limiting fragment mass below which no computations are made. This type of kill probability is more often applicable to target structures, whereas the single fragment vulnerability is commonly used for components.

The last type of P_K is defined by a minimum area removed, below which no damage occurs, and an area which, if removed, will cause complete failure. The kill probability is considered to be linear between these two values.

The user must also specify a material and a skin thickness for each component. The material is chosen from among the ten options provided by the program and listed in the User Manual. A component surface is designated as solid or hollow and either as an internal aircraft component or as an external aircraft component.

Each component's vulnerability (or nonvulnerability) and susceptibility profile is chosen from a list of eleven options which are discussed in Chapter III. The degree of vulnerability is a function of the P_K information as discussed earlier. It is also possible to define the component to be nonvulnerable to specific damage mechanisms. Particular components may be designated as infrared (IR) sources and are therefore susceptible to detection by an IR fuze. Other possibilities include invisibility to EM fuzes.

An individual component kill may or may not constitute a target kill. Aircraft systems can be defined by linking components by logical.AND./OR. statements. The system expression may also include previously defined systems (subsystems). The components are identified by the order in which they were input in the geometric representation. This feature of the program can be used to define both multiply vulnerable components and various levels of kill. For example, a catastrophic kill may be defined as well as a mission kill. The system failure modes are determined by using the results from independent Failure Mode Effects and Critically Analyses and Damage Modes and Effects Analyses.

The SCAN blast model and the warhead model are both similar to the ATTACK models. The SCAN fuzing model consists of only three options: (1) instantaneous detection (2) an IR fuze and (3) a single look angle active fuze.

Scenarios are constructed from one of three possible choices. The user may define a trajectory by fixing the initial missile range from the target and the orientation of the missile relative to the target. The orientation is established by an elevation angle, azimuth angle, angle of attack, and sideslip angle for the missile and by roll, pitch and yaw angles for the target along with an angle of attack and sideslip angle.

A second option requires the user to input a miss distance. This miss distance may be viewed as an offset to the missile aimpoint. It will be the closest point of approach (CPA) of the missile to the specified aimpoint without fuzing consideration. (The numerical value of the miss distance will be dependent on the missile guidance system.) The missile and target are oriented in the same manner as for the fixed trajectory case described above. The program computes the trajectory required to get the missile to the theoretical CPA with the specified orientation. This is a theoretical CPA because it is possible, depending on the fuzing logic selected, that the warhead will detonate prior to reaching this point.

The third option involves the input of a circular error probable (CEP) rather than a specific miss distance. The CEP is a statistical quantity. It represents the radius of a circle inside of which one half (50%) of the missile distance will occur. The trajectory used in the computation

is obtained from a normally distributed sample. The other parameters are identical to those in the specified miss distance option.

Multiple missile trajectories are possible for each specified geometry. The user may take advantage of the statistical capability of the program by providing standard deviation inofrmation for the missile elevation angle, azimuth angle and/or angle of attack.

The SCAN program utilizes the target geometric model and the warhead detonation to determine the number of fragments which impact in the target. The program divides the warhead polar zones and radial zones into a number of elements containing fragments of the same class which are all moving in approximately the same direction. A representative ray is generated to characterize the fragments of each element and the motion of this representative fragment is simulated along a trajectory. A large number of elements are required to ensure all fragments within an element travel in approximately the same direction. This procedure can result in a very time consuming process when the number of fragments is large or when the target is complex. In order to reduce the computation time required, the user must provide limiting parameters. These parameters are associated with the physical dimensions of the target.

Limits are established at values which slightly exceed the target dimensions. No fragment computations are made outside of these limits.

III. COMPARISON OF UTILITY

A. PURPOSE

The intention of this chapter is to examine each program from two aspects. One point of view will be that of a model developer; the other, that of a consumer. In both cases it is assumed the user has no prior familiarity with either program (or with any endgame program).

The comparison study will be conducted with regard to the following six broad subject areas:

(1) Documentation

(2) Target geometric modeling

(3) Probability of Kill/Vulnerable area modeling

(4) Missile, warhead, fuze modeling

(5) Scenario simulation

(6) Output interpretation

The ATTACK objective "is to predict the ability of a missile to detect and destroy an airborne target." SCAN's objective "is to predict the probability that an aircraft will survive an attack by a missile with a fragmentation warhead." These two objectives represent opposite sides of the same coin. This polar relationship will explain many of the differences found between the two programs.

B. DOCUMENTATION

1. General

The ATTACK program documentation consists of two volumes; Volume I: User's Manual and Volume II: Analysis Manual. Both volumes were published in June 1974 under the auspices of the AIR-TO-AIR Subgroup, Air Target End Game Methodology Panel and are Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) publications.

The SCAN documentation was published in July 1976 by the Weapons Evaluation Department, Pacific Missile Test Center, Point Mugu, California. Like ATTACK, there are two volumes, a User Manual and an Analysis Manual. The Analysis Manual is subdivided into two parts.

The User Manuals for both programs are similar in make-up. Each begins with an introduction of the various target/ missile representations used in the respective program. Both include discussions of basic concepts, such as coordinate system definitions.

The bulk of each User Manual is devoted to data input. This section of each manual contains a detailed guide for every input parameter.

In the ATTACK User Manual there is a brief interpretation of the output followed by a sample problem. The SCAN User Manual combines the output discussion with the sample problem

The Analysis Manuals are also similar in format. Each begins with a repeat of the introduction section of the User Manual. Primarily, the Analysis Manuals are composed of detailed discussions of the mathematical models used in the programs. Also included in both manuals are program and subroutine flow charts and source listings, along with abbreviation, symbol and program variable definitions.

In general, the scope of this comparison will deal primarily with the User Manual as the working document. The Analysis Manuals will be compared only as a reference source.

2. <u>User Manuals: ATTACK vs SCAN</u>

The introductory section of each manual is quite good. The user can very quickly learn the objective, use and philosophy of each program and determine the extent of the input data required and the basic capabilities of the program. It is in the input section that differences begin to develop.

a. SCAN

The SCAN program has undergone major modifications since the documentation was published. Entire subroutines have been added. These major changes are not reflected in the source listing of the Analysis Manual or in the User Manual.

(In some cases "pen and ink" changes have been entered in the data input section.) As a result of these major modifications, new input parameters are required that are not indicated in the User Manual.

In general, the published input instructions in the Manual are well written and easy to follow. (An exception to this are some of the "pen and ink" additions which are ambiguous). The fixed format instructions for data input per computer data card are consistently maintained throughout the computer model.

The instruction sequence is:

(1) Column - Computer data card columns allocated to a specific parameter.

(2) Parameter - Variable name (i.e., Boxnum is the variable name used to indicate the number of boxes in the aircraft geometric model).

(3) Units - Units associated with a specific parameter (i.e., feet, inches, degrees, radians, etc.)

(4) Range of Values - Permissable values for that parameter. (i.e., greater than or equal to zero).

(5) Format - Fortran I/O format associated with a specific parameter (i.e., floating point, integer, or alphanumeric).

(6) Description - Parameter definition and amplifying comments.

Most of the modifications to SCAN expand the capabilities of the program. For example, the program gives the user the option to designate the specific case as a "production run". If this option is exercised, the program will generate a limited output. Additionally, the program has been expanded to include the target angle of attack, target sideslip angle, and missile sideslip angle depending on the trajectory option chosen. A feature added to reduce the computational time is input data for limiting the volume of space immediately surrounding the target. This data is used by the program to limit the computations to the specified volume. No input instructions are present in the User Manual for any of these parameters.

With the exception of the limiting parameter data, these missing instructions do not prevent the user from executing the program. The added parameters default to zero which is an acceptable value for program execution. There are no error statements which tell the user information is missing.

b. ATTACK

The ATTACK program utilizes two forms of input, fixed format and namelist. The vulnerable area table is entered via fixed format. Program identification information is input by a fixed form alphanumeric code. The target and the remaining required input is all entered as namelist (variable format) data.

ATTACK, like SCAN, has been significantly modified since the documentation was written and most of these modifications have not been included in the documentation. Many of these discrepancies will be noted on the following pages.

The instructions for vulnerable area data input are, in general, easy to understand and follow. Missing from the User Manual, however, are the instructions for entering vulnerable component names. This naming feature was not part of the original program. Another area of possible confusion is the input of vulnerable areas for fragment impact velocities. The program has the capability to accomodate up to eighteen vulnerable areas per card (one for each impact velocity). Only vulnerable areas for impact velocities two through nine are presently used in the program. The instructions for this data must be carefully read to be understood.

An entire namelist, IFLGS, has been added to the program with no mention in the User Manual. This namelist contains a series of flags which direct program flow. For example, the flag, INTOFT, indicates if the physical geometric dimensions are input in inches or feet. The value of this flag is then used in conditional IF statements to cause a conversion from inches to feet, if necessary. The flag value is also used to select the appropriate WRITE statement.

Modifications have been made to the program to expand the data handling capabilities. Most of the namelists have a flag to indicate if the data contained is new. This gives the user the option of repeating the program execution without changing every namelist. A previously defined namelist (i.e., CONTCT, BLAST, CDML, etc.) may be used for subsequent program execution by inputting the proper value for the flag. Again, there is no mention of these new data flags in the documentation.

A coding system is utilized by the program to identify with which coordinate system a variable is associated. For example, AIM2 represents aim point coordinates in the target coordinate system, and AIM3 represents the same point in a relative coordinate system. AIM2 is the required input. The program performs a transformation to the relative system for computational purposes. The User Manual indicates AIM(1), AIM(2), and AIM(3) are the input variables. The variable AIM is not recognized by the program. AIM2 <u>is used</u> in the sample problem in the User Manual.

The program uses the variables TTS and TMS for target velocity and missile velocity respectively. Again, there is no mention of either variable in the documentation.

The User Manual indicates a necessity to input, RHO, the density of the atmosphere at the target altitude in the AC namelist. In reality, RHO is computed by the program and is not a required input, and if an input of RHO is attempted, an error message will be generated. The

computation is made as a function of TALT, the barometric altitude of the target measured from sea level, which is an input parameter.

One ATTACK parameter definition in the input section is either ambiguous or in error. The definition of VZ(I,J,K) given in the User Manual is "average ejection velocity of the ith fragment class in the jth polar zone and the kth radial zone." This implies for a warhead of one fragment class, one polar zone and one radial zone that only one input velocity is necessary. In reality, two inputs are used in the program, one for the upper polar zone boundary and one for the lower. When this problem was first encountered it was believed to be a "bug" in the program. Since the sample problem in the User Manual inputs two values for VZ the "bug" is evidently in the input instructions.

Model preparation using the ATTACK program requires many iterations due to the failings of the User Manual. The designer must, in many cases, delve into the current program source listing to answer input questions. The section in the Analysis Manual containing parameter definitions is a useful tool in this trouble-shooting process.

3. Documentation Summary

For the purposes of this study the following criteria were used to evaluate the documentation: "A user with no prior experience with a given program could, with

reasonable diligence, design a simple, complete model for that program with a minimal number of errors on the first iteration. Any errors should be correctable by subsequent referral to the User Manual." A simple complete model is considered to be the minimum amount of data in each area (i.e., geometric representation, warhead, fuze, etc.) necessary to execute the program. To say "a minimal number of erros" is to recognize that even the most dutiful individual is prone to misreadings and misinterpretations on a first effort.

The SCAN manual, while not without fault, is very close to fulfilling this criterion. The input instructions are well written and complete. The missing instructions, except for one, do not prevent program execution. The SCAN User Manual was easily revised to reflect the changes in input required, for use at the Naval Postgraduate School.

A few minor changes in the input data were necessary to install the SCAN program at NPS. These changes are incorporated in the NPS version of the User Manual.

The published ATTACK User Manual is unsatisfactory. It is highly improbable any user unfamiliar with the program could design a complete model without a great deal of research. Because the discrepancies are so numerous, the User Manual requires major revisions.

C. TARGET MODELING

1. SCAN Model

The SCAN program provides the user with the capability of constructing a very sophisticated geometric representation of the target. The representation is built from a combination of boxes, polygons (up to six sides), quadric surfaces and bounding planes (see Figure 2-7). The number of shapes is limited to:

(a)	boxes	100
(b)	polygons	300
(c)	quadric surfaces	200
(d)	bounding planes	200

The user may choose from among the eight different quadric surfaces (shown in Figure 3-1). They are:

(a) elliptical cylinder

(b) ellipsoid

(c) paraboloid

(d) elliptical cone

(e) hyperboloid of 1 sheet

(f) hyperboloid of 2 sheets

(g) parabolic cylinder

(h) parabolic hyperboloid

Each individual shape (not including the bounding planes) is considered to be a component. The bounding planes are used to refine the target model. For each component, the user must specify a material and thickness. The material is chosen from the following list:

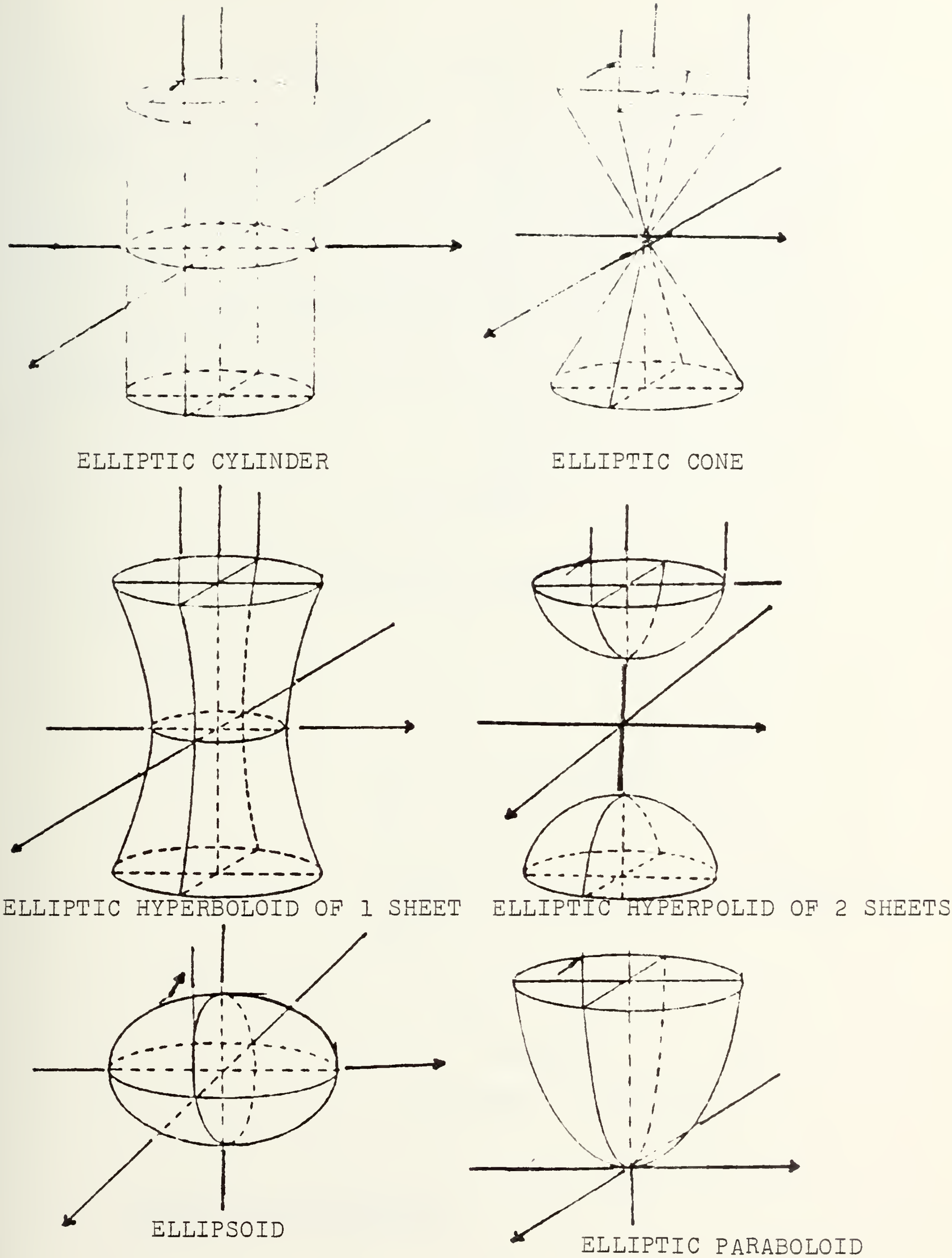
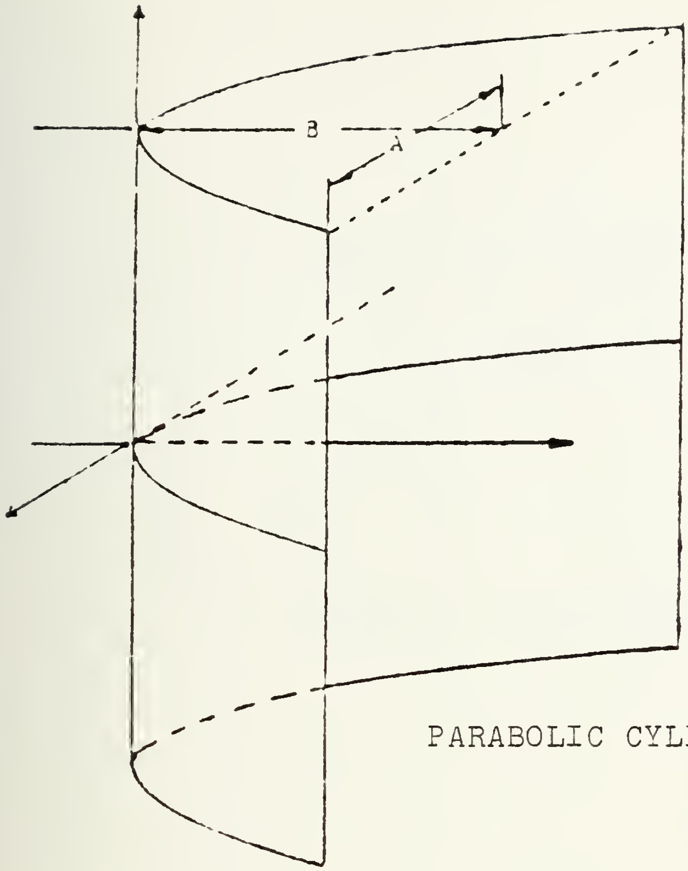
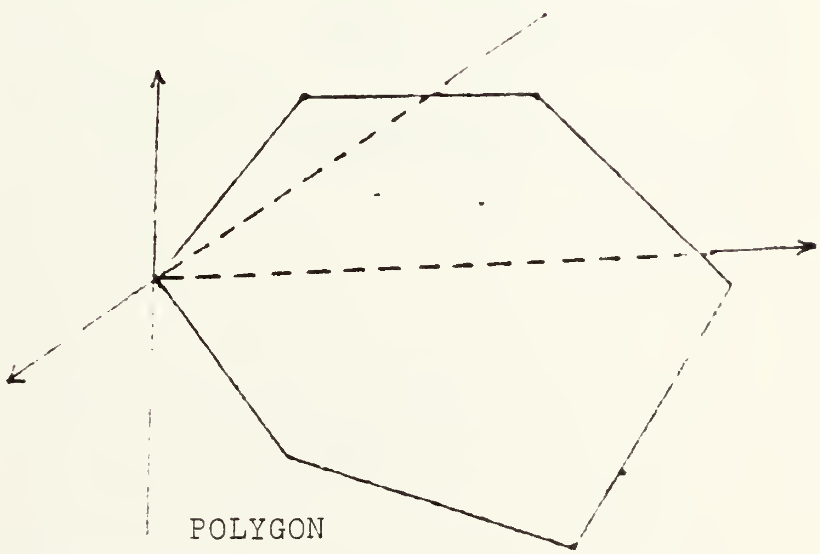


Figure 3-1 SCAN Quadric Surfaces [2]

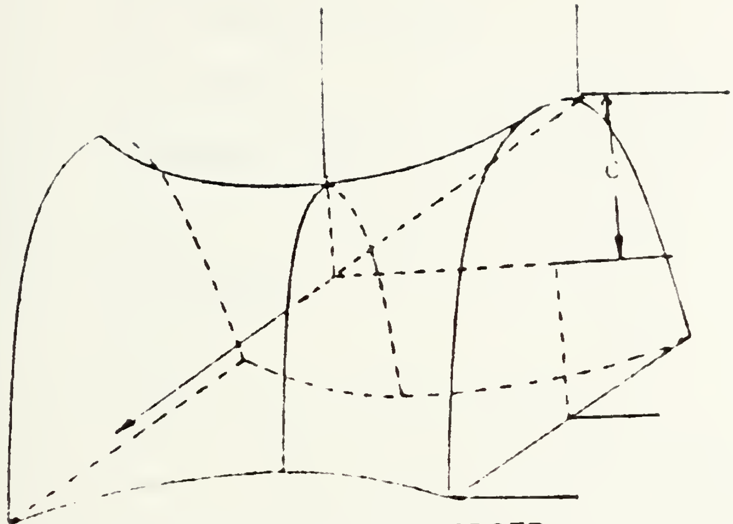


PARABOLIC CYLINDER

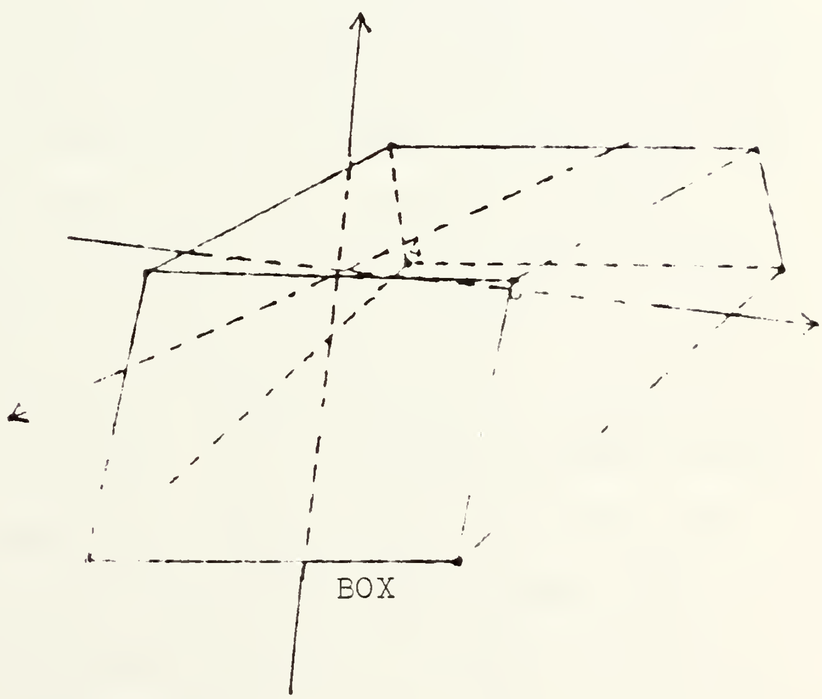


POLYGON

Figure 3-1 (Continued)



PARABOLIC HYPERBOLOID



BOX

Figure 3-1 (Continued)

(a) magnesium

(b) aluminum 2024T

(c) titanium alloy

(d) face hardened steel

(e) mild steel

(f) hardened steel

(g) lexan

(h) plexiglas

(i) doron

(j) bullet resistant glass

Obviously, the capability exists for creating a highly complex, and realistic target representation. Unfortunately, this extensive capability involves a very tedious, time-consuming modeling process when developing complex models. However, this capability for extremely detailed modeling does not inherently overburden the less ambitious modeler. A simple model, such as a "shoe box model", can be handled quite easily. In fact, an entire target could be designed by the input of one shape.

SCAN used this one target geometric representation for computations involving all the damage mechanism except blast. A blast model and a model constructed from the limiting data are also required by the program. The limiting data, as discussed earlier, is used to create a region in space surrounding the target. This is used only to reduce the computer time necessary to execute the program.

Fragment trajectories outside the designated region will not be computed. The user may define this region as large or small as desired, so long as it encompasses the geometric model.

The blast model consists of cylinders with hemispheric caps surrounding the target fuselage and wings. The radius of a specific cylinder, also termed the "blast radius", is the maximum distance from the aircraft centerline (or wing centerline for the wing's cylinder) at which detonation of the warhead will cause catastrophic structural failure of the aircraft at sea level. This distance will be a function of both the amount and type of high explosive used in the warhead and the structural composition and material of the target. The determination of this distance must be accomplished in a separate analysis.

2. ATTACK Models

The ATTACK program requires five target representations. One for each of the possible damage mechanisms plus another for fuze detection or activation purposes. All of the data necessary to construct these models are input via namelist format. (Refer to Table III-1).

The direct hit target model invovles constructing a target skeleton with triangular plates as shown in Figure 2-1. The user is limited to one hundred (100) triangles for this model. A determination is made as to whether the missile will intersect one or more of these plates. The missile model will be discussed later.

TABLE III -1

SUMMARY OF GEOMETRIC REPRESENTATIONS

UTILIZED BY THE ATTACK PROGRAM

MODEL	INPUT NAMELIST	SHAPES	MAXIMUM NO.
Direct Hit	$CONTCT	Triangles	100
Blast	$BLAST	Cylinders and Hemispheric Caps	20
Multiple Fragment (structural)	$CDML	Cylinders (Segments Per Cylinder)	10 10
Single Fragment (component)	$AC	Spheres (or points)	30
Fuzing	$FUZING	Lines (or Sticks)	25

The target blast representation is very similar to the SCAN model covered in a previous section. The cylindrical type representation and the input required are nearly identical.

The multiple fragment (or structural) model represents the target with up to ten cylinders. Each cylinder can be subdivided into as many as ten segments. Each segment may have a different critical energy density threshold value.

The last damage mechanism type target geometric representation is the single fragment or component model. This model is composed of up to 30 components, idealized as spheres, located relative to a target coordinate system origin. Each component (sphere) is assigned a radius to approximate the size of the real target component. This is a significant disadvantage when attempting to represent such components as fuel lines, hydraulic lines or electrical cables. The developer must either use an excessive number of very small spheres to realistically represent any component of this type, or settle for a distorted representation of the component by using larger spheres. For an example of a component model, refer to Figure 2-5.

A fifth representation is used for the fuzing sequence. This representation is similar to the direct model, but less elaborate. A target skeleton is described by defining line segments (or sticks). Up to twenty-five sticks may be used. The intersection of a fuze look angle with any stick in this target skeleton initiates certain events depending on the fuze logic chosen.

3. Summary: ATTACK vs. SCAN

The SCAN program, because of its survivability philosophy, is target oriented. The result is a very elaborate capability for target modeling. While the thrust of this study has been toward aircraft, the program is adaptable to surface ships and land based targets. The ATTACK program is more concerned with the effectiveness of the missile/fuze/warhead and as a result, the target representations are less sophisticated.

The modeling procedures for a realistic complex target can be painstakingly tedious for both programs. The advantage of the SCAN model, besides the ability to provide a realistic representation, is that the same geometric representation is used to evaluate all damage mechanisms except blast. The ATTACK model requires four different difficult representations; a direct hit model, a multiple fragment model, a single fragment model and a fuzing stick model. The difficulty is in detail and the time to prepare, but not necessarily conceptual. (The blast model is not considered difficult for either program).

D. P_K/VULNERABLE AREA MODEL

1. General

The evaluation of target survivability can be broken into two parts: susceptibility and vulnerability.

Susceptibility is the probability that a target will be hit (P_H) by a damage mechanism. This P_H is dependent on a threat's presence and it's detection and tracking capability. For the purposes of this study the probability a threat (missile) is present is assumed to equal unity. SCAN deals with the remaining parts of susceptibility, ATTACK does not. The SCAN options will be discussed in more detail later in this chapter.

Vulnerability is the inability of a target to withstand a hit by a given damage mechanism. The vulnerability depends on many conditions, such as the structural composition of the target and the type, size and impact conditions of the damage mechanism.

The issue of vulnerability is treated differently in each program. ATTACK used a vulnerable area (A_V) approach, while SCAN uses the Probability of Kill given a Hit ($P_{K/H}$) directly. These two concepts are related by the equation

$$P_{K/H} = A_V/A_P$$

Here A_P is the presented area. Both A_V and A_P are aspect dependent.

2. ATTACK: Vulnerable Area

The ATTACK program requires the formation of a vulnerable area table. The data for this table can be generated from experimental information, from analysis, or from other computer programs. The component vulnerable area data is a function of fragment weight, fragment impact velocity, and impact aspect angle.

Currently, the program is capable of creating a table for up to forty aspect angles, seven fragment weights and eight impact velocities. While no specific limit is placed on the number of vulnerable components to be considered, the program had the capability for reading only <u>nine</u> component names. (This has been expanded at NPS to <u>eighteen</u> names and could easily be increased further).

The user may determine his own set of aspect angles or use the default values provided in the program. (Refer to Figure 3-2 and Table III-2).

The quantity of vulnerable area data required for even a small model soon becomes extensive. For card input one vulnerable area for up to eight velocities is entered per card. One card is required for each fragment weight per aspect angle per vulnerable component. It is possible to have up to 182 cards per component if the twenty-six default aspect angles are used. This would require up to 1456 separate vulnerable areas for only one component.

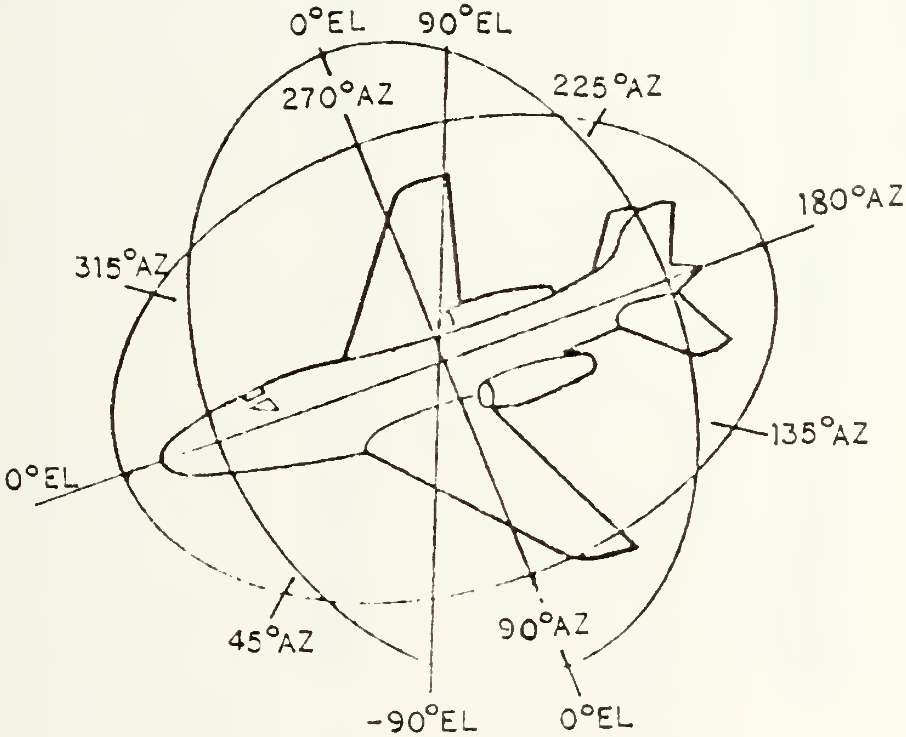


Figure 3-2 Illustration of Vulnerable Area
Area Azimuth and Elevation Angles [1]

TABLE III - 2

ATTACK VULNERABLE AREA TABLE ASPECT ANGLE DEFAULT VALUES

ANGLE NUMBER	ELEVATION (degrees)	AZIMUTH (degrees)
1	-90	0
2	-45	0
3	-45	45
4	-45	90
5	-45	135
6	-45	180
7	-45	225
8	-45	270
9	-45	315
10	0	0
11	0	45
12	0	90
13	0	135
14	0	180
15	0	225
16	0	270
17	0	315
18	45	0
19	45	45
20	45	90
21	45	135
22	45	180
23	45	225
24	45	270
25	45	315
26	90	0

Multiplying these numbers by the number of components gives the total amount of data necessary. Just the vast amount of input required can be a disadvantage to a model developer. From a consumer's point of view, the magnitude of the data can be cumbersome. Obviously, once created, this table would be more efficiently handled if stored on a disk or tape.

The vulnerable area table is used in association with the single fragment, or component, model to compute the component P_K. Vulnerable areas are obtained from the table by interpolation for a specific aspect angle, fragment weight and impact velocity. The procedure for calculating P_K was covered in detail in Chapter II.

Vulnerable components may be combined in a manner such that every component in a combination must be "killed" for the target to be killed. This is useful when dealing with redundant components.

3. ATTACK: Other Vulnerabilities

The ATTACK program investigates types of vulnerability other than single fragment. For example, a vulnerability to blast will be evaluated by the program. The user may specify either a cylindrical radius inside of which a blast kill is attained for a particular warhead at sea level, or a radius for a 1-lb. charge of high explosive (HE) and the program will calculate the "blast KILL radius".

Another type of vulnerability is computed from the multiple fragment model. This is an energy density vulnerability. The user must specify a threshold critical energy density level for each cylindrical segment below which no damage occurs and above which a structural kill occurs. The method used to establish the number of hits for each cylindrical segment is similar to that used in the single fragment component model for spheres.

The final type of vulnerability is for a direct hit. This model was covered in the section on geometric modeling. All targets are considered vulnerable to direct hits.

The ATTACK program sequentially investigates each vulnerability type in the following order:

(a) Direct hit

(b) Blast

(c) Structural (multiple fragment)

(d) Component (single fragment)

If a kill is registered for any type, the target P_K is set to 1.0 and the other types are bypassed. For example, if a blast kill occurs, the possibility of a structural kill or a fragment kill is not examined.

4. <u>SCAN: Vulnerability and Susceptibility</u>

When examining fragment damage, the SCAN user may choose one of three possible vulnerability types for each component. The three types are:

(a) Single fragment vulnerability

(b) Energy density vulnerab lity

(c) Area removal vulnerability

These vulnerability types were discussed in Chapter II.

Like ATTACK, SCAN will also investigate direct hit and blast kills. Unlike ATTACK, a direct hit in SCAN does not preclude examining the results of other damage mechanisms. The SCAN program has been modified at NPS to prevent a blast kill from pre-empting component damage considerations.

The SCAN direct hit model utilizes the target geometric representation and a missile represented by a set of points to determine if the missile body strikes the aircraft prior to warhead detonation by proximity fuzing. If the missile strikes the target the warhead is detonated by contact fuzing producing both fragmentation damage and blast damage.

Another situation examined by SCAN is when proximity fuzing causes warhead detonation before the missile strikes the target. In this case, the missile debris continues along the missile trajectory and may hit the target. SCAN considers both situations in determining the P_K for a direct hit.

There are eleven vulnerability and susceptibility combinations available. The various options are listed in Table III-3. Option number 6 defines a component to be an IR source and therefore susceptible to detection by an

TABLE III - 3

VULNERABILITY/SUSCEPTIBILITY OPTIONS

Option Number	Option Description
1	Energy density vulnerable
2	Single fragment vulnerable
3	Area removal vulnerable
4	Nonvulnerable to fragments direct hit vulnerable
5	Nonvulnerable to fragments and direct hit
6	IR source and nonvulnerable to fragments
7	Energy density vulnerable, invisible to EM fuze
8	Single fragment vulnerable, invisible to EM fuze
9	Area removal vulnerable, invisible to EM fuze
10	Nonvulnerability to fragments, invisible to EM fuze
11	Nonvulnerable, invisible to EM fuze

IR fuze. An example of the use of options 7 through 11 would be for a component with a very small radar cross section (approximately zero) and is therefore invisible to an active electromagnetic (or radar) fuze. A more realistic component representation, but also very complex from a model development standpoint, would be obtained by providing for the utilization of radar cross section data as a function of aspect.

All eleven options listed in Table III-3 consider the target to be vulnerable to blast. A user may simulate blast invulnerability by inputting very small values for the radii of the blast cylinders in the blast model.

SCAN handles very effectively the damage assessment for components shielded by other components or for one component inside another. The program computes the extent of penetration for each fragment group that impacts on a component surface. If a fragment passes through the surface, the residual fragment parameters are determined and utilized to compute the fragment's penetration capability on a subsequent component surface. The program will allow one fragment ray to penetrate up to five surfaces. When a warhead (or primary) fragment penetrates a component surface, pieces of that surface (secondary fragments) are ejected and become damage mechanisms on subsequent surfaces. SCAN assumes these secondary fragments will only damage the next component. For example, secondary fragments

produced from the first component surface struck will not be included in the fragments striking the third component.

The SCAN program provides the capability of defining combinations of components as target systems. The systems consist of components tied together by logical .OR. and .AND. statements. Realistic system survival probabilities can be obtained from proper use of this capability. This is an excellent method for handling both singly vulnerable and multiply vulnerable components.

5. Summary: ATTACK vs SCAN

The results of either program are only as good as the information provided. The assumption has been made here that the vulnerable area data and the $P_{K/H}$ information are accurate and complete in raw form.

The ATTACK program has the disadvantage of the volume of data required to construct the vulnerable area tables. The input to SCAN on the other hand is very compact and is included with the geometric modeling data. Regardless of the mode of component vulnerability chosen, SCAN requires at most three values per component. Note that values are not aspect dependent. If, for example, a model developer wants a higher $P_{K/H}$ on the bottom of a fuel tank than on the top, the tank must be modeled as two components, each with a specific $P_{K/H}$.

SCAN includes susceptibility options. ATTACK pertains only to vulnerability.

ATTACK requires both single fragment and multiple fragment (energy density) models to be input. The SCAN user specifies either single fragment, energy density or area removal vulnerability for each component.

A significant advantage of SCAN is the realistic and flexible method used to define systems and to account for redundancy. ATTACK does not have a true system defining procedure. ATTACK has only a crude component combining process which links together multiple vulnerable components.

E. MISSILE, WARHEAD AND FUZE MODELING

1. General

The missile/warhead/fuze combination will be referred to in this section as the "threat". As will be seen , the warhead models of SCAN and ATTACK are very much alike. ATTACK defines the extent of the missile by a collection of vectors (or points) relative to the missile coordinate system. The missile representation for SCAN is extremely simple. The major differences in the threat model of the two programs are the fuzing capabilities.

2. ATTACK vs SCAN: Missile

The ATTACK program has the capability to define and locate up to ten missile components. The warhead, fuze and

other components are each represented by a point positioned relative to the missile coordinate system origin. These points, which represent the missile, are projected through space and are used to determine such things as direct hits.

The SCAN program simply locates the missile nose and aft end along a straight line relative to the center of the warhead. A missile body radius is also specified.

3. <u>ATTACK vs SCAN: Warhead</u>

Both programs use the concept of fragment spray polar zones and fragment weight classes. The SCAN user may define up to thirty-six polar zones and as many as three fragment weight classes per polar zone. The ATTACK user is limited to ten polar zones and five fragment classes, but also may define up to eight radial zones for nonsymmetric fragment sprays about the warhead centerline.

Both programs define initial fragment velocities within the designated polar and/or radial zones for each weight class. Both programs allow the user to locate the fragments anywhere along the warhead axis and to designate the total number of fragments for each class and zone. ATTACK further requires the input of an average fragment drag area and a coefficient of drag for each fragment class.

Additional SCAN features include the capability to select a fragment material type from a list of ten options. The fragment shape can be designated as cubical, spherical, rectangular or irregular.

4. ATTACK vs. SCAN: The Fuze

SCAN gives the user only three choices for target detection. One choice is instantaneous detection at the missile starting point. The other options are an IR fuze and an active electromagnetic fuze with one look angle.

A component must be designated as an IR source by specifying the proper vulnerability/susceptibility to be detected by an IR fuze. Detection by the active electromagnetic fuze will occur if a ray along the fuze look angle intersects a reflecting surface (target component) within the detection range of the fuze. The detection range is specified by the user.

ATTACK presents the ten fuze options (logics) shown in Table III-4. An eleventh option was incorporated at NPS. The NPS modification allows the user to simulate an instantaneous warhead detonation. This was utilized to control the relative location of the warhead with respect to the target at detonation for the validity study discussed in Chapter IV. The SCAN options most nearly correlate to ATTACK logics 5,6, and 11.

Both programs allow a fuze time delay. This is the time interval from target detection to warhead detonation. ATTACK has the option of specifying a fuze distance delay in lieu of the time delay.

TABLE III-4

LISTING OF FUZE LOGICS

Logic 1	Semi-active doppler fuze
Logic 2	Semi-active doppler fuze with signal stretcher
Logic 3	Semi-active doppler fast truck fuze
Logic 4	Semi-active doppler fuze for intercept arm; fixed angle fuze
Logic 5	Fixed angle active fuze
Logic 6	IR fuze operating in pursuit mode
Logic 7	Active fuze with fore and aft fixed angle fuze cones
Logic 8	Passive fixed angle fuze
Logic 9	Semi-active with guard channel for intercept arm. Fixed angle for home on jam, fuze on jam
Logic 10	Semi-active doppler with guard channel arm
Logic 11*	Instantaneous detection

*Note: This option is an NPS modification

5. Summary

ATTACK is by far more flexible and detailed than SCAN in the area of fuzing. The ATTACK fuzing model is a very useful feature for design of a sophisticated ordnance package. (The ordnance package consists of the warhead and the fuze).

The warhead models are similar. ATTACK provides more flexibility in defining radial zones while SCAN allows for more polar zones. The choice of which program to use would be dictated by the actual specifications of a particular warhead.

F. SCENARIO SIMULATION

1. General

A useful Endgame program must be capable of simulating many diverse encounter geometries. Both ATTACK and SCAN are designed to satisfy this condition.

2. SCAN

SCAN provides three trajectory options. Case one is a fixed trajectory specified by an initial missile range measured from the target center of gravity to the missile center of gravity and expressed in the target coordinate system. Case two is a trajectory with a specified guidance error (miss distance). Case three is a trajectory in which a miss distance is computed from a normal distribution with a specified circular error probable (CEP).

The user provides such parameters as target roll, pitch and yaw angles, target speed, target angle of attack and sideslip angle; missile elevation and azimuth angles with standard deviations, assuming a normal distribution, missile speed, missile angle of attack with standard deviation, encounter altitude and missile aimpoint.

An extensive statistical analysis can be made by specifying one or more non-zero standard deviations, and unlimited number of missile trajectories may be simulated for each case (set of parameters).

The precise location of the warhead detonation is easily controlled by a proper combination of case and fuze options. An initial range can be specified in the case data, and a fuze option for instantaneous detection with no delay time in the fuze data. This is extremely important for a user who wants to generate P_K contours about the target or who is comparing the effects of different warheads on the same target. It could also be used to compare the relative damage inflicted by the same warhead on targets of differing component configurations.

3. ATTACK

The ATTACK user has primarily two options for the missile trajectory. He may specify a set of up to one hundred miss distances relative to an intended aimpoint or he may require the program to generate miss distances by implementing

a Monte Carlo method with a Gaussian distribution.[1] The latter option requires a standard deviation in a plane perpendicular to the relative motion of the target and the missile.

The relative motion coordinate system as used by ATTACK is a right hand system with the positive X direction defined along the vector formed by combing the target and missile velocity vectors.

The user may also specify missile elevation and azimuth angles either in the target coordinate system or the relative system. The missile angle of attack and sideslip angle are also input along with missile and target speeds and encounter altitude.

4. Summary

The SCAN program has more options in the number of available trajectory types and has a greater flexibility for statistical variations. The SCAN encounter geometry specifications are all located in the same input data section. The ATTACK inputs are primarily in the PARAMT namelist, but several encounter parameters are in the AC namelist.

---

[1] While installing the ATTACK program at NPS, a problem was uncovered with the Monte Carlo method. Program execution was terminated by an IMSL error message when this option was attempted. This was traced to the IMSL subroutine GGNML which is used to compute a random number. This subroutine requires a non-zero, double precision seed value. The seed defined in the program did not satisfy either condition. The NPS version has been modified to an acceptable value.

A consumer desiring to examine many varied types of encounters and to establish a sound statistical base should select SCAN. A significant disadvantage of SCAN indirectly related to the encounter geometry is the amount of computer time required for execution. This problem will be addressed later in this chapter.

G. OUTPUT INTERPRETATION

1. General

The most accurate and comprehensive results from any computer program are nearly useless if the program is incomplete or ambiguous. No single output format, however, would be totally satisfactory to every consumer. Each individual user wants specific pieces of information. The quote "one man's signal is another man's noise" seems to apply. Consequently, this section will attempt to highlight the differences in the two outputs.

Both programs provide listings of the target geometric models, warhead data and the blast model. The geometric models are of interest to the model developer since they provide a check of the input data. However, this check could be much more effectively performed with a graphics capability. (NPS does not have a graphics package for either program at this time.)

The ATTACK program provides an echo point of the namelist input, but not the vulnerable area tables. The SCAN input P_K information is output as part of the target geometric model. This can be useful in comparing the relative vulnerabilities of several components.

The SCAN output provides a fairly complete description of the fuze. The fuze data available in the printed output for ATTACK is very sketchy even though some of the ATTACK fuze models are very sophisticated.

Each program gives extensive case descriptions. ATTACK provides tablular summaries for up to ten cases per page. This table contains relative velocities, missile orientations, damage summaries for each type damage mechanism; and overall P_K's. A typical example is shown in Figure 3-3(a). This is followed by a component summary for each case shown in Figure 3-3 (b). The component summary gives the number of expected kills per specified number of missiles for each case. (Only one kill per missile encounter geometry is possible). The component P_K is also listed.

SCAN treats each case separately. Listings of encounter conditions, component summaries and system P_K's are included in the output. A typical printed output is given in Figure 3-4. SCAN provides the range of the warhead at detonation in the target coordinate system. It also indicates the particular components struck by a direct hit. ATTACK

SAMPLE PROBLEM

MISSILE 1 VERSUS TARGET 4

CASE NO.	1.	2.	3.	4.	5.
ALPHA	0.0	0.0	0.0	0.0	0.0
ALPHAR	0.0	0.0	0.0	0.0	0.0
VT	700.	700.	700.	700.	700.
VM	2300.	2300.	2300.	2300.	2300.
VMT	3000.	2191.	1600.	2565.	1869.
TALT	10000.	10000.	10000.	10000.	10000.
EL	0.	0.	0.	45.	-45.
AZ	0.	90.	180.	45.	135.
THETA	0.	0.	0.	52.	-35.
PSI	0.	108.	180.	66.	150.
SIGMA	6.00	6.00	6.00	6.00	6.00
SAMPLE	5.	5.	5.	5.	5.
NOT FUZED	0.	0.	0.	0.	0.
DIRECT HIT PREEMPTION RESULTS					
PREEMPTED	0.	0.	0.	5.	0.
NON-KILLS	0.	0.	0.	5.	0.
BLAST	0.	0.	0.	0.	0.
STRUCTURAL	0.	0.	0.	0.	0.
DAMAGE MECHANISMS TALLY					
DIRECT	0.	0.	0.	0.	5.
BLAST	0.	0.	0.	0.	0.
STRUCTURAL	0.	0.	0.	0.	0.
FRAGMENT	5.	4.	5.	0.	0.
OVERALL SYSTEM EFFECTIVENESS					
PK	0.9443	0.7644	0.5728	0.0	1.0000

(a)

Figure 3-3 Example of ATTACK Computer Printout Results
(a) Case Summary (b) Component Summary

ANALYSIS OF VULNERABLE COMPONENT

PROBABILITY OF KILL

CASE 1

COMPONENT IDENTIFICATION	EXPECTED HITS PER 5 MISSILES	PROBABILITY COMPONENT KILL
PILOT	0.0	0.0
FFILTER	3.6	0.711
F PUMPS	4.0	0.794
SPRAYEAR	0.3	0.064

(b)

Figure 3-3 (Continued)

```
                    SUMMARY OF MISSILE TRAJECTORY NUMBER   45
MISSILE ELEVATION ANGLE WITH RESPECT TO THE AIRCRAFT      -0.03  DEGREES
MISSILE AZIMUTH ANGLE WITH RESPECT TO THE AIRCRAFT    179.72  DEGREES
MISS DISTANCE AT DETONATION (MEASURED PERPENDICULAR TO AIRCRAFT CENTERLINE)     50.00  FEET
CLOSING VELOCITY VECTOR IN TARGET SYSTEM       -11.1    -3000.0      -1.3
RANGE AT DETONATION (IN TARGET  SYSTEM)          0.0        5.0       50.0
```

COMMON NUMBER	NAME OF COMPONENT	COMPONENT MATERIAL	COMPONENT VULNERABILITY	NUMBER OF FRAG. HITS	TOTAL AREA REMOVED FROM COMP. SURFACE	PROBABILITY OF COMPONENT KILL
1	VERT FIN	LEXA	S F VUL	0.0	0.0	0.0
2	VERT FIN	LEXA	S F VUL	0.0	0.0	0.0
3	LEFT FIN	LEXA	S F VUL	0.0	0.0	0.0
4	RT FIN	LEXA	S F VUL	0.0	0.0	0.0
5	RT WING	ALUM 2024	S F VUL	0.0	0.0	0.0
6	LEFT WING	ALUM 2024	S F VUL	0.0	0.0	0.0
7	LE INLET	LEXA	S F VUL	1.00	0.002	1.000
8	LEFT INLET	LEXA	S F VUL	0.0	0.0	0.0
9	TL INLET	LEXA	S F VUL	0.0	0.0	0.0
10	TR INLET	LEXA	S F VUL	0.0	0.0	0.0
11	RT INLET	LEXA	S F VUL	0.0	0.0	0.0
12	LR INLET	LEXA	S F VUL	0.0	0.0	0.0
13	MCM	ALUM 2024	S F VUL	0.0	0.0	0.0
14	CAN GUIDE	ALUM 2024	S F VUL	0.0	0.0	0.0
15	FUZING GEN	ALUM 2024	S F VUL	0.0	0.0	0.0
16	COOLANT PUMP	ALUM 2024	S F VUL	0.0	0.0	0.0
17	WARHEAD FUEL	BUL RES	S F VUL	0.0	0.0	0.0
18	WARHEAD FUEL	BUL RES	S F VUL	0.0	0.0	0.0
19	NOSE COWL	ALUM 2024	S F VUL	0.0	0.0	0.0
20	FWD BODY	ALUM 2024	S F VUL	0.0	0.0	0.0
21	MID BODY	ALUM 2024	S F VUL	0.0	0.0	0.0
22	MID BODY EXT	ALUM 2024	S F VUL	1.00	0.002	[illegible]
23	AFT BODY	ALUM 2024	S F VUL	1.00	0.002	1.000
24	AFT BODY	ALUM 2024	S F VUL	1.00	0.002	[illegible]
25	TAIL CONE	ALUM 2024	S F VUL	3.00	0.018	1.000
26	TAIL CONE	ALUM 2024	S F VUL	1.00	0.006	[illegible]
27	TAIL CONE	ALUM 2024	S F VUL	1.00	0.003	[illegible]
28	WARHEAD	STEE MILD	S F VUL	0.0	0.0	0.0
29	WARHEAD	STEE HARD	S F VUL	0.0	0.0	0.0
30	ENGINE	STEE MILD	S F VUL	1.00	0.0	0.0
31	AIR INLET	LEXA	S F VUL	0.0	0.0	0.0
32	BATTERY	STEE MILD	S F VUL	0.0	0.0	0.0
33	FWD BODY FUE	BUL RES	S F VUL	0.0	0.0	0.0
34	HOPPER FUEL	BUL RES	S F VUL	0.0	0.0	0.0
35	[illegible] FUEL	BUL RES	S F VUL	0.0	0.0	0.0
36	WARHEAD FUEL	BUL RES	S F VUL	0.0	0.0	0.0
37	WARHEAD FUEL	BUL RES	S F VUL	0.0	0.0	0.0
38	AFT FUEL 1	BUL RES	S F VUL	0.0	0.0	0.0
39	AFT FUEL 2	BUL RES	S F VUL	1.00	0.005	0.0
40	AFT FUEL 3	BUL RES	S F VUL	0.0	0.0	0.0
41	AFT FUEL 4	BUL RES	S F VUL	0.0	0.0	0.0
42	AFT FUEL 5	BUL RES	S F VUL	0.0	0.0	0.0
43	AFT FUEL 6	BUL RES	S F VUL	0.0	0.0	0.0
44	AFT FUEL 7	BUL RES	S F VUL	0.0	0.0	0.0
45	AFT FUEL 8	BUL RES	S F VUL	0.0	0.0	0.0
46	AFT FUEL 9	BUL RES	S F VUL	0.0	0.0	0.0
47	AFT FUEL 10	BUL RES	S F VUL	0.0	0.0	0.0
48	AFT FUEL 11	BUL RES	S F VUL	0.0	0.0	0.0
49	AFT FUEL 12	BUL RES	S F VUL	1.00	0.002	0.0
50	AFT FUEL 13	BUL RES	S F VUL	0.0	0.0	0.0

(a)

Figure 3-4 Example of SCAN Computer Printout Results for (a) Component Summary, (b) Overall Survival Probabilities for 45 Trajectories

SURVIVAL PROBABILITIES WITH SAMPLE SIZE = 45

SYSTEM CODES	PROBABILITY OF SURVIVAL	AVERAGE PROB. OF SURVIVAL	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	90 PERCENT CONFIDENCE INTERVAL			NO. OF TIMES SYSTEM SURVIVED
FUELS	1.000	0.734	0.447	0.067	0.622	TO	0.845	33
STRUC	0.0	0.075	0.253	0.038	0.012	TO	0.139	3
WARHD	1.000	1.000	0.0	0.0	1.000	TO	1.000	45
ENGIN	1.000	1.000	0.0	0.0	1.000	TO	1.000	45
HYDEL	1.000	1.000	0.0	0.0	1.000	TO	1.000	45
NAVFC	1.000	1.000	0.0	0.0	1.000	TO	1.000	45
AERO	0.0	0.000	0.000	0.000	0.0	TO	0.000	0
KKILL	0.0	0.075	0.253	0.038	0.012	TO	0.139	3
AKILL	0.0	0.075	0.253	0.038	0.012	TO	0.139	3
CKILL	0.0	0.000	0.000	0.000	0.0	TO	0.000	0
BLAST	1.000	1.000						45
DIRHT	1.000	1.000						45

(b)

Figure 3-4 (Continued)

only indicates the probability a component is killed by fragments. SCAN records the number of fragments hitting each component.

For multiple missile trajectories, ATTACK only lists the results of each encounter and a statistical summary of all encounters. For example, if for one case (set of parameters) a user desires 100 missile trajectories, ATTACK will provide a summary for overall target P_K's for a sample size of 100 and a tally for each type of damage mechanism. The component summary will contain the number of kills expected for 100 missiles. For the same example, SCAN would yield a component summary of fragment hits plus system and overall probability of survival (P_S) data for each trajectory. In addition, up to date (accumulative) statistical computations are given for the system P_S's.

Overall, the SCAN output seems neater, more compact and more informative than the ATTACK output. The ATTACK summary listing of up to ten cases per page is a useful feature.

H. COMPUTER CONSIDERATIONS

1. Time to Execute

One major disadvantage of SCAN is the excessive computer time required by multiple cases and/or trajectories. For example, forty-five separate cases with one trajectory per case required approximately 24 minutes of CPU time on the NPS IBM 360/67 to execute. The same number of runs

in ATTACK with equivalent models required only about 1 minute of CPU time. The internal memory rquirement for both programs is nearly equal (approximately 240-250K bytes.) (The models used for this execution time comparison are the same as those used in Chapter IV.)

The CPU time required for execution is dependent on target geometries, encounter geometries and the warhead. The SCAN execution time is strongly related to the number of fragment trajectories that strike the target (within the limiting envelope). This is caused by the SCAN method of computing individual fragment trajectories. The "fragment collector" approach of ATTACK is much quicker.

The number of fragments that strike the target depends on the encounter conditions at detonation. In an effort to determine the computer time-detonation distance relationship, a series of trajectories were investigated. The same simple models were used as for the validity study (Chapter IV). Each program was executed at miss distances from five to one hundred feet. The results are tabularized in Table III-5. As revealed by these results, the SCAN execution time is very long for extremely close-in conditions, when many fragments hit the target, but becomes comparable to ATTACK at miss distances of approximately 60 feet where fewer fragments hit the target. At distances greater than 60 feet, SCAN is actually less time consuming than ATTACK, which shows time fluctuations, but no significant distance dependence.

TABLE III - 5

COMPUTER CONSIDERATIONS SUMMARY

Distance	CPU TIME SCAN	ATTACK
5 feet	51.89 sec	5.33 sec
10 feet	26.19 sec	6.00 sec
20 feet	15.03 sec	6.54 sec
40 feet	8.47 sec	7.15 sec
60 feet	5.66 sec	5.08 sec
80 feet	3.51 sec	5.46 sec
100 feet	3.73 sec	5.72 sec

In addition to the distance separation between warhead and target, the number of fragment trajectories within the limiting envelope depends, obviously, on the total number of fragments in a warhead. Table III-6 shows the effect of changing the number of fragments on execution time. The SCAN program execution time increases with an increasing number of fragments, whereas ATTACK's execution time remains nearly constant.

2. <u>Input Data Preparation Time</u>

An indication of the preparation difficulty is the number of data cards required to execute a particular program. For the models used to compile the results given in Tables III-5 and III-6, the SCAN input consisted of 90 data cards per encounter. ATTACK required 650 cards per encounter. The primary difference is the vast amount of vulnerable area data needed for ATTACK.

For these same situations, ATTACK provided 278 lines of printed output, while SCAN printed 210 lines.

3. <u>Summary of Computer Requirements</u>

Table III-7 summarizes some of the general computer requirements of each program.

I. CONCLUSIONS

1. <u>Ease of Model Preparation</u>

The current SCAN documentation is much superior to that for ATTACK. An unfamiliar user would encounter many

TABLE III - 6

NUMBER OF FRAGMENT EFFECTS ON EXECUTION TIME

Total Number of Fragments	ATTACK	SCAN
1000	4.41 sec	3.94 sec
2000	4.60 sec	5.12 sec
3000	4.45 sec	7.00 sec

Miss distance = 50 feet

TABLE III - 7

GENERAL COMPUTER REQUIREMENTS

	SCAN	ATTACK
Time to Compute	1 min. 55.93 sec	1 min. 27.12 sec
Core for Compliation	116K	148K
Time to Link	4.52 sec	4.43 sec
Core for Linking	178K	178K
Time to Execute	Variable	Variable
Core for Execution	218K	240K
Source Code Card Deck	4325 Cards	2542 Cards

difficulties when attempting to prepare an ATTACK model due to the numerous inconsistencies and the incompleteness of the User Manual. The SCAN documentation is, in general, well written and easily understood.

Construction of the vulnerable area tables for ATTACK is very difficult, if for no other reason than the magnitude of required data. This problem can be circumvented by utilization of an external source for vulnerable areas such as COVART (Computation of Vulnerable Areas and Repair Time).

The SCAN geometrical model can be very complex. The amount of time and effort required to develop the model is very much the perogative of the user. Even for a simple model for ATTACK, essentially five geometric representations are required.

There is very little difference between the two programs in the amount of time and effort required to prepare the other portions of the input. The threat model, blast model and case data are approximately equivalent with regard to preparation.

One indication of the difficulty with any program is the number of data cards required. As noted in the last section, SCAN requires only a small fraction of the cards needed by ATTACK for the same models and the same encounter conditions.

2. Versatility

SCAN is again far superior with respect to the target model. This program gives the user the capability of constructing a very elaborate and accurate target representation. The ATTACK models are crude in comparison. The SCAN encounter simulation capacity is also more extensive than ATTACK. This is due to more trajectory options available and more opportunities for statistical variation.

On the other hand, ATTACK has a much more sophisticated fuzing capability. The many logics available make this feature very attractive when designing ordnance packages. SCAN's fuze section is not nearly as useful. This points to the differing basic program philosophies-warhead effectiveness vs. aircraft survivability.

The SCAN output seems more informative than the ATTACK output. SCAN provides more detailed information in a more compact format. The usefulness of the information, however, is a function of the consumer and the application.

Depending on the particular models and encounter conditions, SCAN can consume a relatively large amount of computer time. The degree to which this additional computer time is a disadvantage is dependent on the project and the organization.

3. Summary

The utility of ATTACK is only clearly superior to SCAN in the fuzing model and possibly in the computer execution time. In all other areas SCAN is either better or the programs are nearly equal. The biggest ATTACK disadvantage is the poor quality of its User Manual. This factor makes initial utilization of the program extremely difficult.

The strong points of each program could have been predicted from the objectives. SCAN, being target survival minded, has an excellent target representation. ATTACK, which is more warhead oriented, has an excellent fuze/warhead model. The culmination of these philosophies is evident in the output. SCAN reports probabilities of Survival; ATTACK reports probabilities of Kill.

IV. VALIDITY

A. GENERAL

An analysis regarding the relative accuracy or validity of one program with respect to another must be based on two principles.

(1) equivalent inputs

(2) independently verifiable results

In order to compare the results of two programs, the inputs must be equivalent or the comparison is meaningless. Furthermore, no definitive determination as to the accuracy of the results of either program is possible without a third source of solutions. How these two principles were implemented for the validity comparison of ATTACK and SCAN is the subject of the following sections.

Despite the fact that both ATTACK and SCAN are Endgame programs, the nature and form of the input data is in some cases very different, as discussed in Chapter III. Because of these differences, very simple models were prepared for the comparative study. By keeping the models simple and by preparing the ATTACK and SCAN models in parallel, it was possible to avoid any contradictions and inconsistencies in the input.

The necessity of this simplistic approach prohibited exercising much of the capability of both programs. The intent of this comparison is not to undertake a detailed validity analysis of the many features of either program; rather, it is to establish the foundation for a level of confidence in the basic logic of one or both programs.

The emphasis of this chapter is on the component models and single fragment vulnerabilities. Direct hit, energy density, and blast models are included in the discussion, but were not examined in detail.

B. EQUIVALENT INPUTS

1. Target Model

The "shoe box" model shown in Figure 4-1 was chosen for the comparison. This type of model could be easily prepared for both programs with near total certainty of equivalence. The dimensions of the model are 33 feet by 3 feet by 3 feet. The target is divided into eleven identical cubic components. This division was necessary so each component cube could be represented by a sphere in the ATTACK single fragment (component) model without distorting the geometric shape of the target. The representation is symmetric about the centroid of component six. The eleven components are used to define two systems in the SCAN model. The forward system (FWD) is composed of components one through six. Components seven through eleven make up the aft system (AFT).

The SCAN target representation is constructed from eleven boxes. Each box is a 3 foot x 3 foot x 3 foot cube, and the boxes are arranged as shown in Figure 4-1. The assumption is made that any fragment hit on any component will result in a component kill regardless of fragment mass or impact velocity, i.e., each component was designated as single fragment vulnerable with $P_{K/H}$ equal to unity.

The ATTACK contact (direct hit) model consists of twelve triangles. There are two triangles per box side as shown in Figure 4-2.

The single fragment (component) ATTACK model consists of eleven spheres, each with a radius of 1.5 ft. situated along the target axis as shown in Figure 4-3. The sphere centroids of the ATTACK model and the cube centroids of the SCAN model are identically located. Each sphere represents a single fragment vulnerable component. The vulnerable area tables for ATTACK were computed assuming the vulnerable areas were equal to presented areas. The presented area for each component was manually computed for each of the 26 aspect angles. These computations were not difficult due to the simplicity and symmetry of the shoe box model. Therefore, $P_{K/H}$ equals one for ATTACK, which is the same as the SCAN component model.

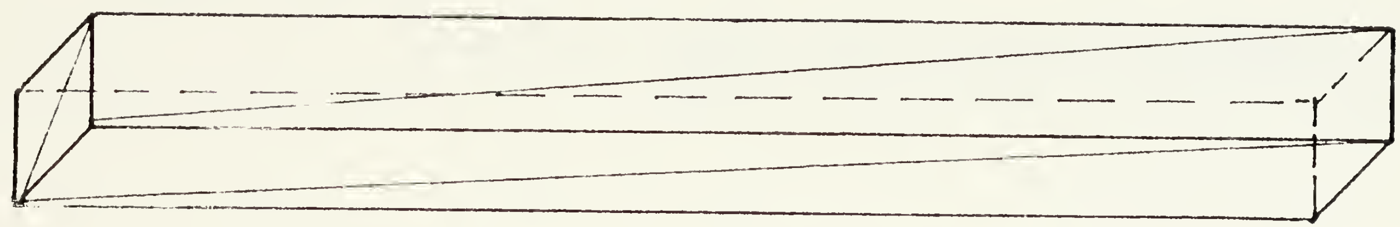


Figure 4-1 "Shoe Box" Target Model

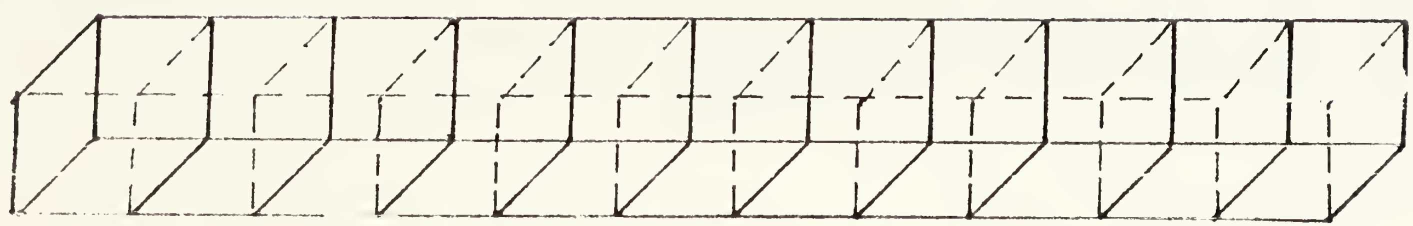


Figure 4-2 ATTACK Contact (Direct Hit) Representation of the "Shoe Box" Target Model

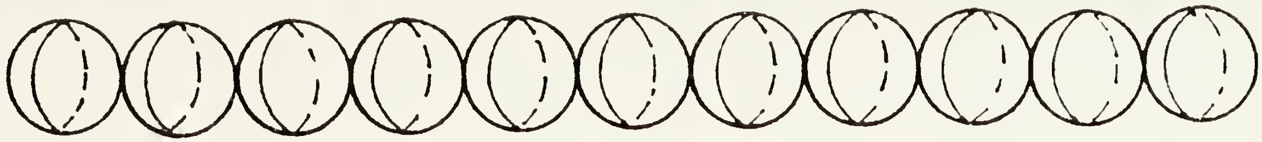


Figure 4-3 ATTACK Single Fragment (Component) Representation of the "Shoe Box" Target

Figure 4-4 ATTACK Multiple Fragment (Structural) Representation of the "Shoe Box" Target Model

The ATTACK multiple fragment (structural) model is represented by a single cylinder of only one segment as shown in Figure 4-4. This is an energy density type model and was included merely for completeness and is not used in the comparison. This model was bypassed during execution by defining the no area on the cylinder vulnerable to an energy density type mechanism.

Due to the similarity in the SCAN and ATTACK blast models, equivalent blast representations are not difficult to develop. The validity of either program's blast model was not within the scope of this study. As with the structutal model, the blast models are included only for completeness.

The other target representation prepared was a stick model for the ATTACK fuze mode. This representation is composed of twelve lines, one for each edge of the shoe box. This model does not have a SCAN counterpart. Since a fuze option resulting in instantaneous detection was chosen, the stick representation was not utilized.

2. Fuze and Warhead

A simple warhead containing one polar zone, one radial zone, one weight class (105 grains) and one initial fragment velocity (5180 ft/sec) was used for the comparison. Two thousand fragments of identical size, shape and material composition were assumed. The fragment static spray angles

were 75 degrees and 105 degrees. All fragments were assumed to emanate from the warhead center. The warhead center of gravity was placed coincident with the missile center of gravity. This was done to avoid confusion when referring to the location (or range) of the missile or warhead with respect to the target at detonation. The option in SCAN specifying initial detection was chosen with a zero delay time for detonation and the fuze logic 11 that was added to the NPS ATTACK program was used. This logic gives ATTACK the capability of instantaneous detection and detonation. The added option was necessary to ensure that the warhead was detonated at the same location by both programs.

3. Scenarios

A valid comparison of the program results requires identical encounter conditions. Care was taken to ensure that the target and missile speeds and the relative to the target by proper setting of the amipoint and miss distance parameters. The fuze options were specified as discussed previously.

Three classical encounter geometries were selected for comparison; parallel head on, parallel tail chase and crossing. Fifteen trajectories were examined for each encounter type. The trajectories comprised warhead detonation ranges of 5 ft., 10 ft., 15 ft., 20 ft., and 25 ft., above, below and to one side of the target centroid.

A total sample of 45 trajectories for each program was studied with respect to single fragment vulnerable components. The results of 40 of these trajectories are reported in Tables IV-1 through IV-8. The crossing encounter geometry with warhead detonation to the side of the target was not included in the tabularized data because both programs indicated direct hits for all five trajectories. As a result the ATTACK program bypassed the single fragment model. Sample printoutsof the input models and the results for SCAN and ATTACK are shown in Figures 4-5 and 4-6 respectively.

C. VERIFIABLE RESULTS

A manual analysis of any encounter for verification purposes is made possible by choosing simple models and simple encounter geometries. This external source for solutions is required to establish a validity base. An example of one of these plots in illustrated in Figure 4-7. This particular encounter is for a tail chase scenario with the detonation point 10 feet above the target. The warhead is symbolized by a point. The aspect of the figure is from a direct side view.

Fragment dynamic spray angles (Ø) were calculated using

$$Ø = \text{Arctan}\left[\frac{(V_0 \text{ Sin } \alpha)}{(V_r + V_0 \text{ Cos } \alpha)}\right]$$

where V_0 is the initial fragment velocity

V_r is the relative encounter velocity

α is the corresponding static spray angle

The fragments will fly out in the zone between the front and rear dynamic spray angles. In this example, components four, five and six are struck by fragments as shown in Figure 4-7. Table IV-1 shows that both SCAN and ATTACK models indicate hits on these same components at a miss distance of 10 feet. This plotting technique was used as the independent analysis to verify the results of a sampling of the 40 trajectories selected arbitraily.

D. ANALYSIS OF THE RESULTS

The results of the two programs correlated very well. For the forty encounters summarized in the Tables, 440 component hit possibilities existed. Of these 440 trajectories, contradictory results between ATTACK and SCAN occured only eleven times (2.5%).

Ten of these contradictions resulted from SCAN indicating a component was hit that was not indicated by ATTACK; only once was the reverse true. In six of these ten cases, the "extra" component was struck by fewer fragments than any other component in that SCAN encounter. This observation is made possible because SCAN reports the number of fragments hit

TABLE IV - 1

ATTACK vs. SCAN TAIL CHASE TYPE ENCOUNTER

WARHEAD DETONATES ABOVE TARGET

Range at Detonation

	5 ft	10 ft	15 ft	20 ft	25 ft
Comp 1	---	---	---	---	S^-/A
Comp 2	---	---	---	S/A	S/A
Comp 3	---	---	S/A	S/A	S/A
Comp 4	---	S/A	S^+/A	S/A	S^+/A
Comp 5	S^+/A	S^+/A	S/A	S^+/A	S/A
Comp 6	S^-/A	S^-/A	S^-/A	S^-/A	S
Comp 7	---	---	---	---	---
Comp 8	---	---	---	---	---
Comp 9	---	---	---	---	---
Comp 10	---	---	---	---	---
Comp 11	---	---	---	---	---

Notes: (1) SCAN component hits are denoted by "S"

(2) ATTACK component hits are denoted by "A"

(3) S^+ indicates the component struck by the most fragments in the SCAN model

(4) S^- indicates the component struck by the fewest fragments in the SCAN model

TABLE IV - 2

ATTACK vs. SCAN TAIL CHASE TYPE ENCOUNTER

WARHEAD DETONATES BESIDE TARGET

Range at Detonation

	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.
Comp 1	---	---	---	---	A
Comp 2	---	---	---	A/S^-	A/S
Comp 3	---	---	A/S	A/S	A/S
Comp 4	---	A/S	A/S^+	A/S	A/S
Comp 5	A/S^-	A/S^+	A/S	A/S^+	A/S
Comp 6	A/S^+	A/S^-	A/S^-	A/S^-	S^-
Comp 7	---	---	---	---	---
Comp 8	---	---	---	---	---
Comp 9	---	---	---	---	---
Comp 10	---	---	---	---	---
Comp 11	---	---	---	---	---

Notes: (1) SCAN component hits are denoted by "S"

(2) ATTACK component hits are denoted by "A"

(3) S^+ indicates the component struck by the most fragments in the SCAN model

(4) S^- indicates the component struck by the fewest fragments in the SCAN model

TABLE IV - 3

ATTACK vs. SCAN TAIL CHASE TYPE ENCOUNTER

WARHEAD DETONATES BELOW TARGET

Range at Detonation

	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.
Comp 1	---	---	---	---	A/S^-
Comp 2	---	---	---	A/S^-	A/S
Comp 3	---	---	A/S	A/S	A/S^+
Comp 4	---	A/S	A/S^+	A/S^+	A/S
Comp 5	A/S^-	A/S^+	A/S	A/S	A/S
Comp 6	A/S^+	A/S^-	A/S^-	A/S^-	S^-
Comp 7	---	---	---	---	---
Comp 8	---	---	---	---	---
Comp 9	---	---	---	---	---
Comp 10	---	---	---	---	---
Comp 11	---	---	---	---	---

Notes: (1) SCAN component hits are denoted by "S"

(2) ATTACK component hits are denoted by "A"

(3) S^+ inidcates the component struck by the most fragments in the SCAN model

(4) S^- indicates the component struck by the fewest fragments in the SCAN model

TABLE IV - 4

ATTACK vs. SCAN HEAD ON TYPE ENCOUNTER

WARHEAD DETONATES ABOVE TARGET

	Range at Detonation				
	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.
Comp 1	---	---	---	---	---
Comp 2	---	---	---	---	---
Comp 3	---	---	---	---	---
Comp 4	---	---	---	---	---
Comp 5	---	---	---	---	---
Comp 6	S^-	---	---	---	---
Comp 7	A/S^+	A/S	---	---	---
Comp 8	A/S	A/S^+	A/S	A/S^-	---
Comp 9	---	A/S^-	A/S^+	A/S^+	A/S^-
Comp 10	---	---	A/S	A/S	A/S^+
Comp 11	---	---	A/S^-	A/S	A/S

Notes:

(1) SCAN component hits are denoted by "S"

(2) ATTACK component hits are denoted by "A"

(3) S^+ indicates the component struck by the most fragments in the scan model

(4) S^- indicates the component struck by the fewest fragments in the SCAN model

TABLE IV - 5

ATTACK vs. SCAN HEAD ON TYPE ENCOUNTER

WARHEAD DETONATES BESIDE TARGET

	Range at Detonation				
	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.
Comp 1	---	---	---	---	---
Comp 2	---	---	---	---	---
Comp 3	---	---	---	---	---
Comp 4	---	---	---	---	---
Comp 5	---	---	---	---	---
Comp 6	S	---	---	---	---
Comp 7	A/S^+	A/S^-	---	---	---
Comp 8	A/S^-	A/S^+	A/S	A/S^-	---
Comp 9	---	A/S	A/S^+	A/S	A/S^-
Comp 10	---	---	A/S	A/S^+	A/S
Comp 11	---	---	A/S^-	A/S	A/S^+

Notes: (1) SCAN compnent hits are denoted by "S"

(2) ATTACK component hits are denoted by "A"

(3) S^+ indicates the component struck by the most fragments in the SCAN model

(4) S^- indicates the component struck by the fewest fragments in the SCAN model

TABLE IV - 6

ATTACK vs. SCAN HEAD ON TYPE ENCOUNTER

WARHEAD DETONATES BELOW TARGET

Range at Detonation

	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.
Comp 1	---	---	---	---	---
Comp 2	---	---	---	---	---
Comp 3	---	---	---	---	---
Comp 4	---	---	---	---	---
Comp 5	---	---	---	---	---
Comp 6	S	---	---	---	---
Comp 7	A/S^+	A/S^-	---	---	---
Comp 8	A/S^-	A/S^+	A/S	A/S^-	---
Comp 9	---	A/S	A/S^+	A/S^+	A/S
Comp 10	---	---	A/S	A/S	A/S^+
Comp 11	---	---	A/S^-	A/S	A/S

Notes: (1) SCAN component hits are denoted by "S"

(2) ATTACK component hits are denoted by "A"

(3) S^+ indicates the component struck by the most fragments in the SCAN model

(4) S^- indicates the component struck by the fewest fragments in the SCAN model

TABLE IV - 7

ATTACK vs. SCAN CROSSING TYPE ENCOUNTER

WARHEAD DETONATION ABOVE TARGET

Range at Detonation

	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.
Comp 1	---	---	---	---	---
Comp 2	---	---	---	---	---
Comp 3	---	---	---	---	---
Comp 4	S^-	---	---	---	---
Comp 5	A/S	---	---	---	---
Comp 6	A/S	---	---	---	---
Comp 7	A/S^+	---	---	---	---
Comp 8	A/S	---	---	---	---
Comp 9	---	---	---	---	---
Comp 10	---	---	---	---	---
Comp 11	---	---	---	---	---

Notes: (1) SCAN component hits are denoted by "S"

(2) ATTACK component hits are denoted by "A"

(3) S^+ indicates the component struck by the most fragments in the SCAN model

(4) S^- indicates the component struck by the fewest fragments in the SCAN model

TABLE IV - 8

ATTACK vs. SCAN CROSSING TYPE ENCOUNTER

WARHEAD DETONATION BELOW TARGET

Range at Detonation

	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.
Comp 1	---	---	---	---	---
Comp 2	---	---	---	---	---
Comp 3	---	---	---	---	---
Comp 4	S	---	---	---	---
Comp 5	A/S	---	---	---	---
Comp 6	A/S^+	---	---	---	---
Comp 7	A/S	S	---	---	---
Comp 8	A/S	---	---	---	---
Comp 9	S^-	---	---	---	---
Comp 10	---	---	---	---	---
Comp 11	---	---	---	---	---

Notes: (1) SCAN component hits are denoted by "S"

(2) ATTACK component hits are denoted by "A"

(3) S^+ indicates the component struck by the most fragments in the SCAN model

(4) S^- indicates the component struck by the fewest fragments in the SCAN model.

```
                  TARGET GEOMETRICAL DESCRIPTION

CONVERSION FACTOR NAME IS    FEET
BOX
COMP  1        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  1  COMMON NUMBER  1  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
  16.500       16.500       13.500     13.500     13.500    16.500     16.500     13.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP  2        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  2  COMMON NUMBER  2  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
  13.500       13.500       10.500     10.500     10.500    13.500     13.500     10.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP  3        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  3  COMMON NUMBER  3  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
  10.500       10.500        7.500      7.500      7.500    10.500     10.500      7.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP  4        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  4  COMMON NUMBER  4  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
   7.500        7.500        4.500      4.500      4.500     7.500      7.500      4.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP  5        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  5  COMMON NUMBER  5  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
   4.500        4.500        1.500      1.500      1.500     4.500      4.500      1.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP  6        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  6  COMMON NUMBER  6  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
   1.500        1.500       -1.500     -1.500     -1.500     1.500      1.500     -1.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP  7        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  7  COMMON NUMBER  7  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
  -1.500       -1.500       -1.500     -4.500     -4.500    -1.500     -1.500     -4.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP  8        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  8  COMMON NUMBER  8  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
  -4.500       -4.500       -7.500     -7.500     -7.500    -4.500     -4.500     -7.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP  9        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER  9  COMMON NUMBER  9  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
  -7.500       -7.500      -10.500    -10.500    -10.500    -7.500     -7.500    -10.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP 10        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER 10  COMMON NUMBER 10  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
 -10.500      -10.500      -13.500    -13.500    -13.500   -10.500    -10.500    -13.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
COMP 11        ALUM  2024    0.015 IN. THICKNESS   BOX NUMBER 11  COMMON NUMBER 11  PKH   0.100E 01  0.0      0.0
   S F    VUL  VULNERABLE    AND    EXTENAL   SKIN COMPONENT
   1.500       -1.500       -1.500      1.500      1.500     1.500     -1.500     -1.500
 -13.500      -13.500      -16.500    -16.500    -16.500   -13.500    -13.500    -16.500
  -1.500       -1.500       -1.500     -1.500      1.500     1.500      1.500      1.500
FINIS
```

(a) Target Geometric Model

Figure 4-5 SCAN Computer Printouts for Comparison and an Example of Results

WARHEAD FRAGMENTATION DATA

POLAR ZONES (DEG)		INITIAL FRAGMENT VELOCITIES (FPS)		FRAGMENT MASS (GRAINS)	NUMBER OF FRAGMENTS	DISTANCE FROM WARHEAD CENTER	FRAGMENT MATERIAL	FRAGMENT SHAPE
75.0	105.0	5180.0	5180.0	105.00	2000.0	0.0	STEEL HARD	[illegible]

FUZE DATA

```
FUZE TYPE        0
FUZE POSITION (RELATIVE TO WARHEAD)        3.25  FEET
DELAY TIME       0.0      SEC.
FUZING ANGLE          90.0   DEGREES
STANDARD DEVIATION OF FUZING ANGLE        0.0     DEGREES
RANGE CUTOFF        20.000   FEET
RADIUS OF MISSILE         1.500  FEET
NOSE OF MISSILE IS        6.500  FEET IN FRONT OF THE WARHEAD
TAIL OF MISSILE IS        6.500  FEET IN BACK  OF THE WARHEAD
```

BLAST MODEL

```
RADIUS OF FUSELAGE CYLINDER       10.00
CYLINDER LENGTH FORWARD OF CG       16.50
CYLINDER LENGTH AFT OF CG       16.50
RADIUS OF WING CYLINDER       0.0
STARTING POINT OF CYLINDER (WING ROOT)       1.50       2.50       0.0
END POINT OF CYLINDER (WING TIP)       1.510       2.500       0.0
```

FACTORS USED TO DECREASE RUN TIME

```
MAXIMUM LENGTH OF TARGET (MEASURED FROM TARGET CG)    34.0  FEET
MAXIMUM WIDTH OF TARGET(MEASURED FROM TARGET CG)     4.0  FEET
MAXIMUM HEIGHT (MEASURED FROM TARGET CG)     4.0  FEET
MAXIMUM EXTENSION OF TAIL SURFACE FROM CG      2.00  FEET
DISTANCE BETWEEN FRAGMENT RAYS     0.10  FEET
DISTANCE BEYOND WHICH WARHEAD IS NO LONGER CONSIDERED EFFECTIVE     50.0  FEET

WING LEADING EDGE - FROM      1.500     2.500     0.0   TO      1.510     2.500     0.0  (FEET)
WING TRAILING EDGE - FROM      1.510     2.490     0.0   TO      1.500     2.490     0.0  (FEET)

H-S STABILIZER LEADING EDGE - FROM      1.500    -15.000     0.0   TO     1.510    -15.000     0.0    (FEET)
H-S STABILIZER TRAILING EDGE - FROM      1.510    -15.100     0.0   TO     1.500    -15.100     0.0    (FEET)

VERTICAL TAIL LEADING EDGE - FROM      0.0     -15.000     1.500 TO     0.0     -15.000     1.510  (FEET)
VERTICAL TAIL TRAILING EDGE - FROM      0.0     -15.100     1.510 TO     0.0     -15.100     1.500  (FEET)
```

(b) Warhead, Fuze and Blast Models and Limiting Data

Figure 4-5 (continued)

```
          CASE DATA

NUMBER OF MISSILES IN SAMPLE            1
VELOCITY OF THE TARGET             700.00   FEET/SEC
TARGET ROLL ANGLE                    0.0    DEGREES
TARGET PITCH ANGLE                   0.0    DEGREES
TARGET YAW ANGLE                     0.0    DEGREES
VELOCITY OF THE MISSILE           2300.00   FEET/SEC
NOMINAL MISSILE ATTACK ANGLE         0.0    DEGREES
STAND. DEV. OF ATTACK ANGLE          0.0    DEGREES
NOMINAL MISSILE ELEVATION ANGLE      0.0    DEGREES
STAND. DEV. OF ELEVATION ANGLE       0.0    DEGREES
NOMINAL MISSILE AZIMUTH ANGLE        0.0    DEGREES
STAND. DEV. OF AZIMUTH ANGLE         0.0    DEGREES
ENCOUNTER ALTITUDE               10000.00   FEET
NOMINAL AIM POINT (WRT TARG CG)      0.0      0.0      0.0   FEET
TGT VEL VER ANG            0.0
TGT VEL HOR ANG            0.0
FLAG, TRAJECTORY            MISSILE INITIAL POSITION W.R.T. TARGET CG =,      5.000      0.0      0.0    FEET
MSL VEL VER ANG            0.0
MSL VEL HOR ANG            0.0
```

(c) Case Data

Figure 4-5 (Continued)

```
                         SUMMARY OF MISSILE TRAJECTORY NUMBER    1
MISSILE ELEVATION ANGLE WITH RESPECT TO THE AIRCRAFT      0.0   DEGREES
MISSILE AZIMUTH ANGLE WITH RESPECT TO THE AIRCRAFT      0.0   DEGREES
MISS DISTANCE AT DETONATION (MEASURED PERPENDICULAR TO AIRCRAFT CENTERLINE)      5.00  FEET
CLOSING VELOCITY VECTOR IN TARGET SYSTEM        0.0     1600.0       0.0
RANGE AT DETONATION (IN TARGET SYSTEM)        5.0        0.0        0.0
```

COMMON NUMBER	NAME OF COMPONENT	COMPONENT MATERIAL	COMPONENT VULNERABILITY	NUMBER OF FRAG. HITS	TOTAL AREA REMOVED FROM COMP. SURFACE	PROBABILITY OF COMPONENT KILL
1	COMP 1	ALUM 2024	S F VUL	0.0	0.0	0.0
2	COMP 2	ALUM 2024	S F VUL	0.0	0.0	0.0
3	COMP 3	ALUM 2024	S F VUL	0.0	0.0	0.0
4	COMP 4	ALUM 2024	S F VUL	0.0	0.0	0.0
5	COMP 5	ALUM 2024	S F VUL	86.00	0.957	1.000
6	COMP 6	ALUM 2024	S F VUL	134.00	1.179	1.000
7	COMP 7	ALUM 2024	S F VUL	0.0	0.0	0.0
8	COMP 8	ALUM 2024	S F VUL	0.0	0.0	0.0
9	COMP 9	ALUM 2024	S F VUL	0.0	0.0	0.0
10	COMP 10	ALUM 2024	S F VUL	0.0	0.0	0.0
11	COMP 11	ALUM 2024	S F VUL	0.0	0.0	0.0

(d) Component Summary

Figure 4-5 (Continued)

SURVIVAL PROBABILITIES WITH SAMPLE SIZE = 1

SYSTEM CODES	PROBABILITY OF SURVIVAL	AVERAGE PROB. OF SURVIVAL	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	90 PERCENT CONFIDENCE INTERVAL	NO. OF TIMES SYSTEM SURVIVED
FWD	0.0	0.0				0
AFT	1.000	1.000				1
BLAST	0.0	0.0				0
DIRECT	1.000	1.000				1

(e) Overall P_S Summary

Figure 4-5 (Continued)

VULNERABLE COMPONENTS IN THE TARGET SYSTEM - CENTROID COORDINATES AND COMPONENT RADII ARE EXPRESSED IN FEET - NO.= 11

NUMBER	X2	Y2	Z2	RADIUS	NUMBER	X2	Y2	Z2	RADIUS
1	15.00	0.0	0.0	1.50	2	12.00	0.0	0.0	1.50
3	9.00	0.0	0.0	1.50	4	6.00	0.0	0.0	1.50
5	3.00	0.0	0.0	1.50	6	0.0	0.0	0.0	1.50
7	-3.00	0.0	0.0	1.50	8	-6.00	0.0	0.0	1.50
9	-9.00	0.0	0.0	1.50	10	-12.00	0.0	0.0	1.50
11	-15.00	0.0	0.0	1.50					

NUMBER OF MULTIPLY VULNERABLE COMPONENT COMBINATIONS SPECIFIED IS 11 - MAX NO OF COMPONENTS IN A COMBINATION IS 1

COMBINATION NO. 1 IS MADE UP OF VULNERABLE COMPONENTS 1
COMBINATION NO. 2 IS MADE UP OF VULNERABLE COMPONENTS 2
COMBINATION NO. 3 IS MADE UP OF VULNERABLE COMPONENTS 3
COMBINATION NO. 4 IS MADE UP OF VULNERABLE COMPONENTS 4
COMBINATION NO. 5 IS MADE UP OF VULNERABLE COMPONENTS 5
COMBINATION NO. 6 IS MADE UP OF VULNERABLE COMPONENTS 6
COMBINATION NO. 7 IS MADE UP OF VULNERABLE COMPONENTS 7
COMBINATION NO. 8 IS MADE UP OF VULNERABLE COMPONENTS 8
COMBINATION NO. 9 IS MADE UP OF VULNERABLE COMPONENTS 9
COMBINATION NO. 10 IS MADE UP OF VULNERABLE COMPONENTS 10
COMBINATION NO. 11 IS MADE UP OF VULNERABLE COMPONENTS 11

(a) Component Model

Figure 4-6 ATTACK Computer Printouts for Comparison and an Example of Results

```
WARHEAD MODEL HAS  1 FRAGMENT CLASSES,  1 POLAR ZONES,  1 RADIAL ZONES - WEIGHTS ARE IN GRAINS AND ZONE ANGLES IN DEGREES

POLAR ZONE APICES ARE    0.0    0.0
POLAR ZONE ANGLES ARE   75.0  105.0
RADIAL ANGLES ARE        0.0  360.0

FRAGMENT   FRAGMENT  REFERENCE    DRAG      POLAR      RADIAL     NO. OF   L BOUNDARY   U BOUNDARY
CLASS NO.  WEIGHT      AREA      COEFF.   ZONE NO.   ZONE NO.  FRAGMENTS  VELOCITY     VELOCITY

    1      105.00   0.000510  1.200000      1          1       2000.00    5180.00        0.0
```

(b) Warhead Model

Figure 4-6 (Continued)

ATTACK VS SCAN

MISSILE 1 VERSUS TARGET 1

CASE NO.	1.	2.	3.	4.	5.
ALPHA	0.0	0.0	0.0	0.0	0.0
ALPHAR	0.0	0.0	0.0	0.0	0.0
VT	700.	700.	700.	700.	700.
VM	2300.	2300.	2300.	2300.	2300.
VMI	1600.	1600.	1600.	1600.	1600.
TALT	10000.	10000.	10000.	10000.	10000.
EL	0.	0.	0.	0.	0.
AZ	180.	180.	180.	180.	180.
THETA	0.	0.	0.	0.	0.
PSI	180.	180.	180.	180.	180.
SIGMA	0.0	0.0	0.0	0.0	0.0
SAMPLE	1.	1.	1.	1.	1.
NOT FUZED	0.	0.	0.	0.	0.
DIRECT HIT PREEMPTION RESULTS					
PREEMPTED	0.	0.	0.	0.	0.
NON-KILLS	0.	0.	0.	0.	0.
BLAST	0.	0.	0.	0.	0.
STRUCTURAL	0.	0.	0.	0.	0.
DAMAGE MECHANISMS TALLY					
DIRECT	0.	0.	0.	0.	0.
BLAST	0.	0.	0.	0.	0.
STRUCTURAL	0.	0.	0.	0.	0.
FRAGMENT	1.	1.	1.	1.	1.
OVERALL SYSTEM EFFECTIVENESS					
PK	1.0000	1.0000	1.0000	1.0000	1.0000

(c) Case Summary

Figure 4-6 (Continued)

ANALYSIS OF VULNERABLE COMPONENT
PROBABILITY OF KILL
CASE 1

COMPONENT IDENTIFICATION	EXPECTED HITS PER 1 MISSILES	PROBABILITY COMPONENT KILL
COMP 1	0.0	0.0
COMP 2	0.0	0.0
COMP 3	0.0	0.0
COMP 4	0.0	0.0
COMP 5	1.0	1.000
COMP 6	1.0	1.000
COMP 7	0.0	0.0
COMP 8	0.0	0.0
COMP 9	0.0	0.0
COMP 10	0.0	0.0
COMP 11	0.0	0.0

(e) Component Summary

Figure 4-6 (Continued)

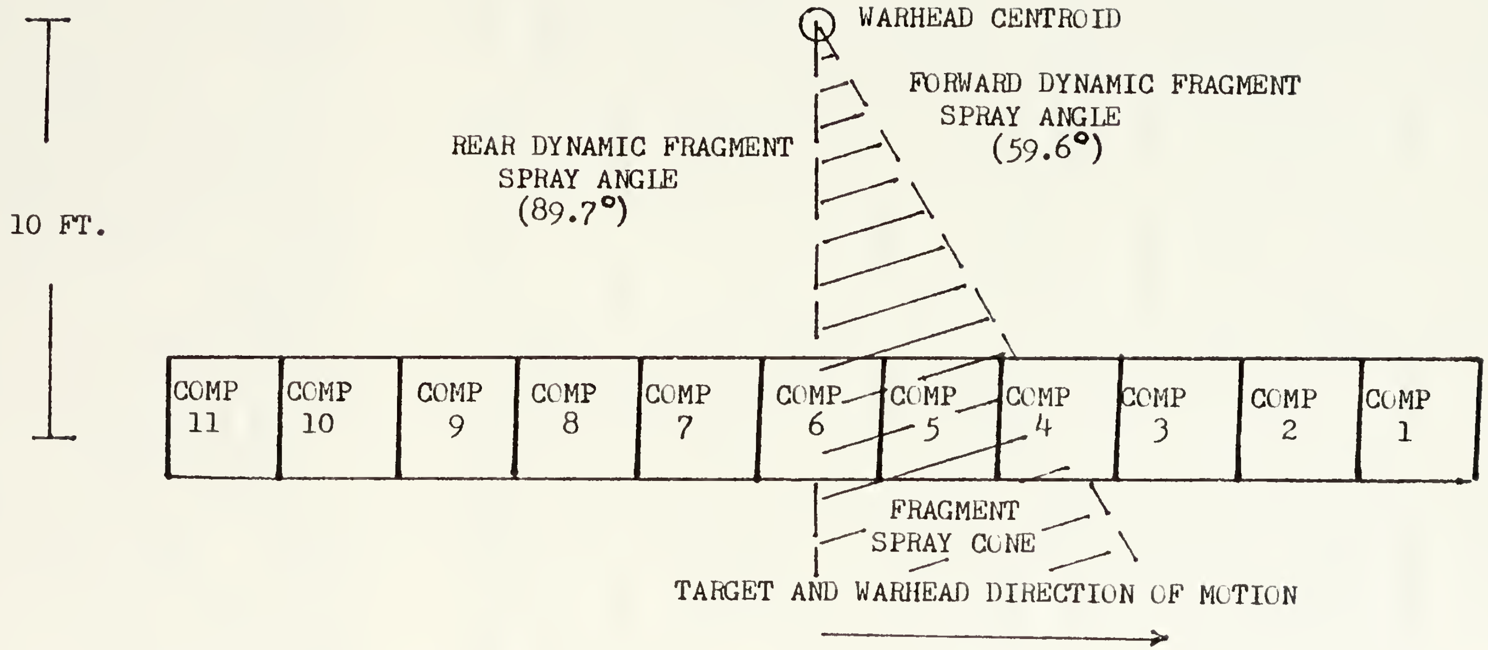


Figure 4-7 Example of Manual Plot Technique

on each component.[1] This number is the sum of the primary fragments (warhead originated) and the secondary fragments (component debris produced by a fragment impacting a component surface) that strike and penetrate a component. Fewer than 5% of the total impacting fragments struck the "extra" component in most cases. For example, in the head-on encounter with a miss distance 5 feet above the target, component six was struck by 13 out of a total of 534 primary and secondary fragment hits (2.4%). The number of secondary fragments produced is dependent on the mass and velocity of the impacting primary fragment.

An exception to the above observation was the head on encounter with the warhead detonating 5 feet below the target (Table IV-6), when component six was struck by 38 of 111 fragments (34.2%) that hit the target. The manual plot technique predicted a very small portion of component six inside the fragment spray cone. The disproportionate number of fragment hits on component six is probably due to a relatively large number of secondary fragments.

---

[1] The number of fragment hits on the target reported for a given detonation distance was found to be dependent on the placement of the warhead relative to target at detonation (i.e. above, below, beside). For a symmetric shoe box model and for the classical head on and tail chase encounter geometries, this dependence should not exist. The cause of the difference is unknown at present, but the SCAN program developer has been informed of the problem. The placement dependence was found to affect the prediction accuracy of which components were struck by fragments. The numbers cited in this section for fragment hits for specific encounters should not be considered as precise quanitative data but is presented only to establish the relative degree of difference for the ATTACK and SCAN contradictory encounters.

Every case that was checked by a manual plot supported the results of the two programs with respect to which components were hit by fragments. In the SCAN/ATTACK contradictory cases, the extra component was always found to be on the fringe of the fragment spray cone.

From this analysis, it appears that the results of both programs are valid for the model and trajectories used for comparison. No significant discrepancy except as has been noted could be found in the results of eith program, and there was an excellent correlation among the ATTACK and SCAN results and the manual plots.

V. CONCLUSIONS

A. STRENGTHS, WEAKNESSES AND RECOMMENDATIONS

The difference in the program objectives cited in Chapter II is the key to understanding the merit of each program. Each program has areas of strength in keeping with the emphasis of the objective.

SCAN possesses an excellent potential for target geometric modeling. This coupled with a flexible, easy to understand method for system definition provides a versatile total target representation. The SCAN program is recommended for any study pertaining to specific target component or system vulnerabilities.

The SCAN program does not have the capability for extensive fuze modeling. This would preclude use of this program for such purposes as ordnance package design or fuze optimization.

SCAN has a very good terminal encounter simulation model. This feature is useful for any application.

ATTACK has an excellent fuze model. With the eleven logics inherent to the program and options such as time delay or distance delay, a realistic and complex fuzing sequence is possible. The ATTACK model is recommended for warhead/fuze analyses.

One major ATTACK weakness is the poor quality of supporting documentation. This could be resolved to a degree acceptable to a new user by a careful and thorough rewrite of the User Manual.

ATTACK's target geometric representations are fairly crude relative to SCAN's. This may or may not be a significant disadvantage. From the view point of a consumer interested in warhead performance, the target is probably not of over-riding concern. On the other hand, an aircraft designer would require SCAN's capacity for detail.

Table V-1 provides a listing of Endgame program applications and a recommendation for SCAN or ATTACK. The applications are taken from the program purposes stated in each program's documentation. Table V-2 is a summary of the findings of this report. The areas listed are the ones investigated in Chapters III and IV.

SCAN is clearly the more useable program, but is also the most expensive to execute. The program's limited fuze options can be a significant liability however. A useful project would be to incorporate ATTACK type fuze models into the SCAN program. This combination would give the user the "best of both worlds." The SCAN program should also be examined to see if the execution time could be reduced.

TABLE V - 1

PROGRAM APPLICATIONS AND RECOMMENDATIONS

APPLICATION	RECOMMENDED PROGRAM
Aircraft Design	SCAN
Aircraft Survivability Studies	SCAN
Supporting Data for Implementation of survivability feature	SCAN
Weapon System Evaluation	ATTACK
Warhead Design	ATTACK
Fuze Optimization	ATTACK
Trade-Off Studies	EITHER *

*depends on whether warhead or target is being studied with respect to trade-offs.

TABLE V - 2

SUBJECT AREA SUMMARY

Subject Area	Superior Program
Documentation	SCAN
Geometric Modeling	SCAN
P_K/Vulnerable Area Modeling	SCAN
Missile, Warhead, Fuze Modeling	ATTACK
Scenario Simulation	SCAN
Output Interpretation	SCAN
Validity	EQUAL*

*Neither program demonstrated a clear superiority for the models and scenarios studied.

B. MISCELLANEOUS

A new Endgame program, Reference Model (REFMOD), has recently been developed under the supervision of the Naval Weapons Center, China Lake. This program was evidently designed with the intention of replacing ATTACK. Because of this, the availability of ATTACK models is limited and therefore studies with ATTACK using "canned" models are difficult. A comparison similar to the one made here should be made using REFMOD vs. SCAN. One was conducted at the Wright Patterson Air Force Base. That study compared SCAN to SESTEM (an in-house Endgame program at Wright Patterson). A conclusion from that study was that the current linear P_K/H equations used by SCAN should be replaced by a non-linear representation. The following equation was recommended for implementation:

$$P_K = C_0 \; (1 - \mathrm{EXP} \; (C_1 * M^{C_2} * (V-V_0)^{C_3}))$$

where C_0 ---maximum value P_K

C_1 ---scaling factor

C_2 ---variation in slope factor

C_3 ---deviation from linearity factor

V_0 ---fragment velocity value for P_K 0

A disadvantage of this non-linear form is a more extensive and more complex input data requirement.

These new and modified programs are mentioned here to show that there is no one absolutely correct or best Endgame program. The survivability and warhead communities are constantly seeking to provide more realistic and comprehensive computer models.

BIBLIOGRAPHY

Air-to-Air Subgroup, Air Target End Game Methodology Panel Publication, ATTACK computer Program, Volume I. User Manual, June 1974.

Air-to-Air Subgroup, Air Target End Game Methodology Panel Publication, ATTACK Computer Program, Volume II. Analysis Manual, June 1974.

Ball, R. E., Krumbholz, K. O., and Nosco, R., Aircraft Combat Survivability Analysis and Design: The Fundamentals of, (Draft), Sept. 1979.

Cottfried, B. S., Programming with FORTRAN IV, Quantus, 1972.

Naval Weapons Center Technical Note 4565-1-70, Air-to-Air Terminal Encounter Simulation Computer Program I, Volume III. Fuze Addendum, by J. E. Musch and John E. Strong, May 1973.

Weapons Evaluation Department, Pacific Missile Test Center Publication, SCAN, A Computer Program for Survivability Analysis, Volume I, User Manual, July 1976.

Weapons Evaluation Department, Pacific Missile Test Center Publication, SCAN, A Computer Program for Survivability Analysis, Volume II. Analyst Manual, July 1976.

LIST OF REFERENCES

1. Air-to-Air Subgroup, Air Target End Game Methodology Panel Publication, ATTACK Computer Program, Volume I, User Manual, June 1974.

2. Weapons Evaluation Department, Pacific Missile Test Center Publication, SCAN, A Computer Program for Survivability Analysis, Volume I, User Manual, July 1976.

INITIAL DISTRIBUTION LIST

		No. of Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 31 Department of Aeronautical Engineering Naval Postgraduate School Monterey, California 93940	1
4.	Professor R. E. Ball, Code 31 Department of Aeronautical Engineering Naval Postgraduate School Monterey, California 93940	2
5.	LT James Earl Parr, USN RR1 Box 206 Leavenworth,Indiana 47137	1
6.	Mr. P. Coffield AD/DLYD Eglin AFB, Florida 32542	1
7.	Mr. K. Grant, Code 318 Naval Weapons Center China Lake, California 93555	1
8.	Mr. Bruce Nofrey, Code 1332 Pacific Missile Test Center Point Mugu, California 93042	1

Thesis 191442
P188 Parr
c.1 ATTACK vs SCAN: a
comparison of endgame
aircraft survivability
computer programs.